Industrial QUALITY CONTROL

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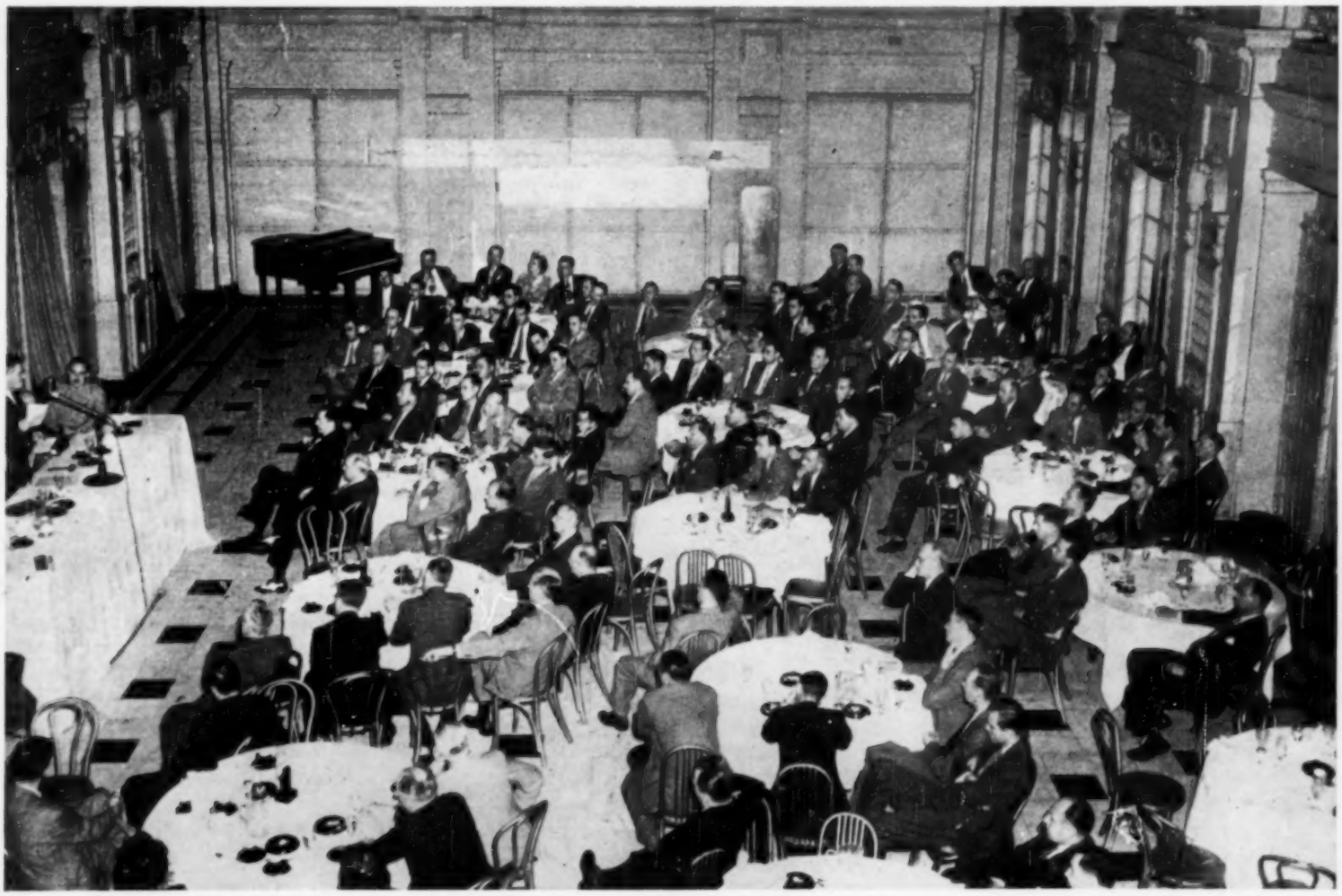

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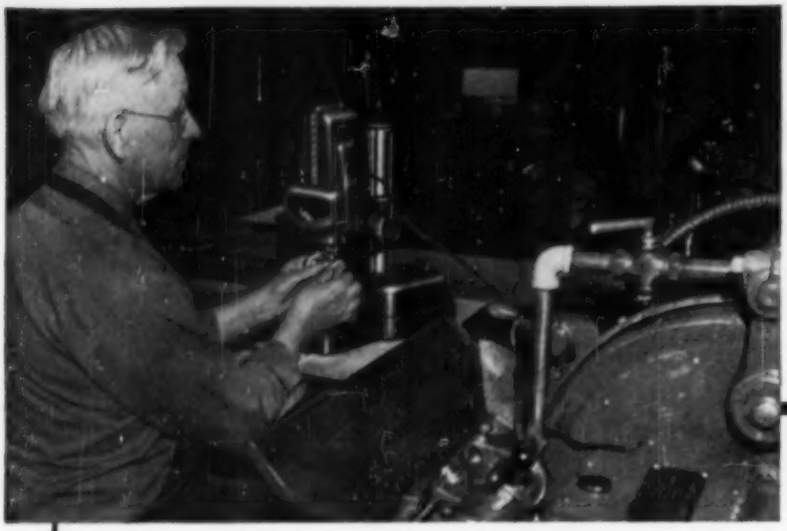
AMERICAN SOCIETY FOR QUALITY CONTROL



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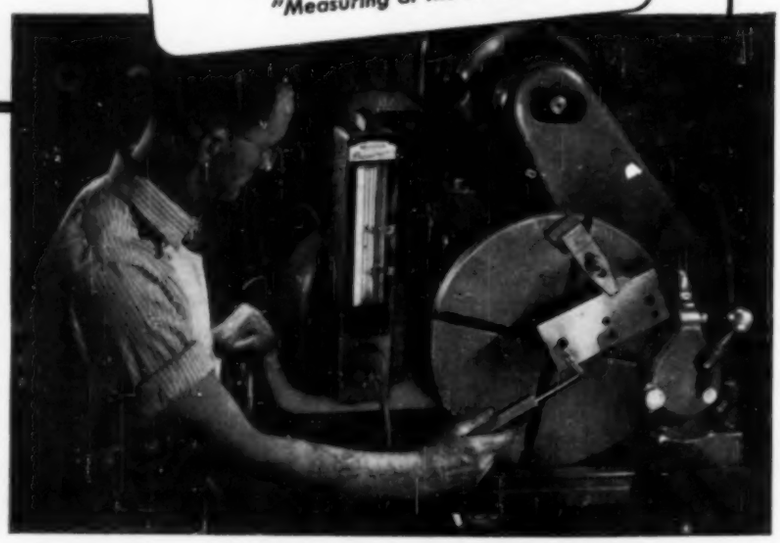
chek with Sheffield on "Measuring at the Machine"

1767



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ACCEPTANCE SAMPLING COURSE NEWARK COLLEGE OF ENGINEERING

The Newark College of Engineering is presenting a Training Conference on Acceptance Sampling to be held at the Robert Treat Hotel, Newark, New Jersey, on the following eleven Friday afternoons (2:30 to 5:30) and evenings (7:30 to 9:30): Sept. 27, Oct. 4, 11, 18, 25, Nov. 1, 8, 15, 22, Dec. 6, 13.

The staff includes Professors Paul Clifford, S. B. Littauer, and O. J. Sizelove for the whole conference and Dr. B. L. Clarke, Mr. Harold F. Dodge, Professor H. A. Freeman, Mr. G. R. Gause, Professor Frederick Mosteller, Paul Peach, Mr. A. I. Peterson, Dr. W. A. Shewhart, and Col. L. E. Simon as special lecturers.

The college's Advisory Panel on Industrial Statistics, comprised of Mr. A. I. Peterson, Chairman, Dr. B. L. Clarke, Professor S. B. Littauer, Dr. W. A. Shewhart, Professor O. J. Sizelove, and Professor S. S. Wilks, have selected the following major topics for conference consideration: Basic Reasons for Sampling, Basic Problems of Statistical Inference, The O. C. Curve, Assumptions Underlying the Design of Sampling Plans, Classification of Sampling Plans, Dodge Romig, Ordnance, Navy, and Peach-Littauer Sampling Tables, D.P.U. Plans, the A.O.Q.L. Concept for Lot Sampling and Continuous Production, The Grand Lot Schema, Double Sampling Plans, Comparison of Single and Multiple Sampling Plans, Future Developments in Industrial Sampling.

A 24-hour course in Basic Statistics will be offered during September, preceding the conference, for those who feel that a statistics refresher will aid them in benefiting from the conference.

Local Societies 100% American

In the following local Societies, 100% of the local members are now also members of the American Society for Quality Control:

Society for Quality Control—University of Iowa Group.

Michigan Society for Quality Control.

Society for Quality Control—Omaha Group.

Atlanta Quality Control Society.

Table of Contents

	Page
Acceptance Sampling Course	3
Second Report of Midwest Quality Control Conference	
The Relation of the Quality Function to the Industrial Enterprise, J. M. Juran	5
Fundamentals of Quality Control, Lloyd A. Knowler	
I Principles	7
II Average and Range Charts	10
III Application of Average and Range Charts	14
IV Fraction Defective Chart	16
Tables to Facilitate Computation of Sampling Limits of s and Limits of σ, Frederick E. Croxton and Dudley J. Cowden	18
The Difference Control Chart with an Example of its Use, Major Frank E. Grubbs	22
Report of Michigan Forum	25
Society Reports	28
American Society News	
Meeting of Executive Committee	31
Additional Local Societies	31
General Committees	4
Local Societies 100% American	3

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Membership in The American Society for Quality Control is available through local society sections or directly through the Executive Secretary. Annual dues are five dollars for direct national membership. Information concerning local societies should be obtained from local secretaries.

Founding Memberships in the Society are available prior to July 1, 1947 by an additional payment of five dollars or more.

General Information

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INDUSTRIAL QUALITY CONTROL
was founded in 1944 by the
SOCIETY OF
QUALITY CONTROL ENGINEERS
BUFFALO
in cooperation with
THE UNIVERSITY OF BUFFALO

Organization of General Committees

On 10 May, 1946, the President of the American Society sent a letter to the Chairmen or Presidents of all local Society Sections asking each of them to nominate five of their local members for appointment, one to each of five general Committees of the American Society.

The work of all of these general Committees is vital to the immediate progress of the American Society, and it is hence most important that they be activated at the earliest possible moment. Local Society Chairmen and Presidents are therefore urged to make their nominations as soon as they can do so. These are nominations and not appointments, so that it is not essential that they be ratified by local Societies before they are made.

Mr. Walter S. Oliver of the Michigan Society has been appointed General Chairman of the Committee on Membership.

The remaining four general committees, each with an Executive Chairman, will work under the General Chairmanship of Andrew I. Peterson, Vice-President of the American Society.

The Executive Chairmen are: Mr. Frank A. Palumbo, Illinois Society, Committee on Programs and Speakers; Mr. Harold F. Dodge, Newark Society, Committee on Relations with Technical Societies; Mr. Ernest H. Robinson, Chicago Society, Committee on Publicity and Public Relations; Mr. A. C. Richmond, Illinois Society, Committee on Relations with Educational Institutions.

COVER PICTURE

This picture was taken during Professor J. M. Juran's address at the Banquet of the Mchigan Quality Control Forum, held in the Book Cadillac Hotel in Detroit. (Photographer: S. Zafron).

SECOND REPORT OF MIDWEST Quality Control Conference

The Relation of the Quality Function to the Industrial Enterprise

JOSEPH M. JURAN

CHAIRMAN, DEPARTMENT OF ADMINISTRATIVE ENGINEERING
NEW YORK UNIVERSITY

[**Presented at Afternoon Session, March 5**]

It was at the Western Electric Company's Hawthorne Plant in Chicago that there was undertaken, starting in 1924, the first large scale application of modern quality control techniques. I was at the time a cub engineer when such men as G. D. Edwards, W. A. Shewhart, and H. F. Dodge came to that plant to outline new techniques developed in the Bell Telephone Laboratories. Some of the principles we developed have endured to this day. Others have been rendered obsolete by the march of progress. It took years of work and many kinds of changes to extend the applications of these principles to so large a plant. But the results were gratifying. An inspection force of about 5,000 was reduced to a force of about 2,000, and yet the smaller force certified the same amount of production as had the larger force. Necessarily, the reduction in the loss due to defects was correspondingly formidable.

It was my privilege to be close to the quality function, in this plant and others, for over ten years, starting as a shop inspector and advancing through the grades to head of the inspection division. From this experience and from a later experience in the problems of top management, both in industry, I propose to deal with the subject in its broad and fundamental aspects rather than in techniques.

We may well start by the realization that the phenomenon which has given rise to increased emphasis on the quality function is the rise of precision. The earliest industries posed no problems in precision as we define that word today. Farming, hunting, fishing, home-spinning and weaving, or the construction of crude houses offered no 20th century problems in precision.

With the coming of the Power Age and the associated rise of manufacture, the need for precision increased sharply. Furthermore, manufacture itself, while growing, has shifted in emphasis from low-precision to high-precision manufacture. The growth of large integrated industries requiring high degrees of interchangeability; the development of aircraft and other forms of transport requiring absolute reliability of performance; the amazing growth of the electrical and electronic industries necessitating high fidelity and long life; the dawn of synthetics; the growth of competition in quality—these events are among the most dynamic in the history of manufacture.

Finally, in all industry, whether manufacturing or other, whether high-precision or low-precision, precision itself has tightened up. Consider, in the field of agriculture, the recent developments in the breeding of farm animals, the growing of hybrid grains, and the preservation of foods. Here the wave of precision has swept back to engulf the most ancient of industries. On the forward side, the closing in of tolerances in mechanical and electrical apparatus, and the tightening of tolerances in physical characteristics and chemical purity are too familiar to require elaboration.

On all accounts, the rise of manufacture, the increasing emphasis on high precision products, and the closing in of tolerances, it is clear that we are witnessing an unparalleled rise of precision. Measured on a scale of centuries, an index of precision would be rising in geometric proportion. This is a deep and fundamental change.

The fact that such a change was slow in developing has tended to obscure its presence. Yet for many companies the war dramatized the change. They were suddenly brought face to face with new problems in precision, and were not fully prepared. In consequence scrap losses during war-time were very high, too high to have a place in a world of competition. Moreover, so deep and fundamental a change necessarily effects all parts of the industrial enterprise—not just the top, or the bottom, or the spe-

cialist. Top management is always affected by a major change in the pattern of industry. The main trunks of the organization are involved, some to a remarkable extent. The change may call for new habits on the part of some of the people at the bottom. The change may require development of a new skill or profession. Finally, such a change affects the relations of each company with the suppliers, the customers, and the competitors. A company cannot produce greater precision in vacuo; it must secure greater precision from its suppliers. All are affected—the professions, the schools, the press.

Granting the existence of this deep and fundamental change, it becomes the responsibility of the industrial executive:

1. To recognize the existence and significance of the change. (This is one of the highest responsibilities of the executive.)

2. To take action in the light of this understanding.

What, then, is **the quality problem?** In brief, **the quality problem is to establish, for each characteristic of the specification, the optimum balance between the cost of quality and the value of quality.** By a quality **characteristic** I mean one item of the specification — a limited dimension, a maximum on phosphorous content, a minimum on tensile strength. By **quality** I mean both quality of design and quality of conformance. Quality of design, sometimes called "grade," refers to variation in specification for the same functional use, whereas quality of conformance refers to the fidelity with which the product meets the demands of the design specification.

Years ago, Edwards[1] showed that there is an optimum to quality of design, and that above or below this optimum, the margin between cost and value shrinks. In like manner, there is an optimum to quality of conformance. Above or below this optimum, the cost of conformance is greater than the cost at the optimum. This elemental problem—to find, for each characteristic of the specification, the best balance between the cost of quality and the value of quality—is the building block of the quality function. It is this elemental problem, multiplied many, many times, which constitutes the overall quality problem of industry.

Although I have stated the elemental problem as applying to one quality characteristic, there are in fact thousands of these characteristics. They are so numerous that it is out of the question to strike the "best balance" in the high levels of the organization. The balance must be struck at the lower levels of the organization, or not at all. This leads to a restatement of the problem—how to secure, in the lower levels of organization, the collection of the essential facts, and the co-ordinated consideration of those facts, so as to strike, for each quality characteristic, the optimum balance between cost of quality and value of quality.

A good rule-of-thumb is to determine what is being lost through failure to conform to specification. To do this there should be computed or estimated how much is being lost through:

(1) Scrap and junk
(2) Disassemble, rework, reasasemble
(3) "Extra" operations
(4) Detail inspections when sampling might do
(5) Customers' quality returns
(6) Excessive service to customers.

The total of this is approximately the amount of "gold in the mine." The order of magnitude of this total is the guide to the size of the corrective action which can be justified.

Actually, the total indicated above does not reflect the less tangible losses such as productive delays and stoppages, irregular deliveries, or higher inventories. On the other hand, it does not pay to reduce the total to zero, since the point of diminishing returns sets in first. Neither does the above total state the positive side of good quality—the reputation such as has been achieved for china by Wedgwood, or violins by Stradivarius. Nor does the total state the potential risk of great and perhaps fatal blows to quality reputation through blunders or frauds. The importance of the order of magnitude of the amount of "gold in the mine" cannot be overstated. Without such knowledge, the top company officials cannot judge how much of an attack should be made on the problem—how much engineering effort, how much supervision, how much consulting service, how much research, how much training.

To solve the problem—to strike that optimum balance—actually involves several undertakings by the industrial company. I list these as five in number, and consider them as being about equal in weight. I would call these:

a. Quality-mindedness
b. Organization
c. Engineering
d. Management tools
e. All else.

Quality-mindedness Human experience is full of proofs that state of mind is of great importance in achieving an objective. A plant with a good sofety record needs safety-mindedness quite as much as mechanical safety devices. The soldier must be put into the correct state of mind before he can use his weapons to the best effect. Quality-mindedness is no exception. Change of state of mind always involves an indoctrination—a propaganda. This is a training or educational process and should include top executives as well as intermediate officials and first-line supervisors. All should understand the new emphasis, the role each is to play, and the importance of a co-ordinated attack.

Organization involves giving adequate recognition to the quality function and to the people who have the responsibilities. It includes setting up the necessary staff assistance. If, for example, there is no clear-cut answer to the question "Whose job is it to investigate the cause of defective work?", then there exists an important piece of unfinished business in the field of organization. In my experience, a company which faces the need for setting up a staff group to deal with these problems can minimize jurisdictional disputes by setting the group up in some existing trunk of the organization rather than creating a new trunk of organization. The risk of the latter procedure is that the new organization will spend months or years

(1) G. D. Edwards "Standard Quality," Bell Telephone Quarterly, Vol. VII, pp. 292-303, October, 1928.

acquiring jurisdictional rights before it can function properly. If, however, it can be set up to function promptly, the correct organization solution will become apparent much sooner.

Engineering includes specification writing, process engineering, instrumentation, and related engineering jobs. Much of this is well handled. In my experience, this job usually is done better than the other four; yet there is still much room for improvement, particularly in the writing of specifications. The ideal setup is to engineer controlled quality into the job at the outset, much as is sometimes done with factory layout and production control. But with respect to quality control, this is as yet something visionary.

Management techniques include scientific sampling, rating of quality of product, quality incentives to operators and inspectors, control charts, quality audits or surveys, and executive reports. Currently, much activity is under way toward developing and improving these techniques, and it may well be that a high degree of effectiveness of these tools can be attained. Any program for improving the quality performance in a company should certainly include liberal training in the application of these techniques to actual work situations.

All else There remain elements of the problem such as research, advertising, collaboration in professional society undertakings, and still others. Very likely, as the deep and fundamental change unfolds itself, we shall learn of new methods of attack not yet discovered. Certainly the new competition in quality will require a new form of advertising in quality. As to this, we will have to collaborate with our advertising brethren. But certainly we want to avoid the unfortunate advertisement of Product X. This showed a cross-section of Product X and its limited dimensions, with large type proclaiming that here was why the Product X could never be mass-produced. Actually, the limited dimensions eloquently testified that here was why Product X **could** be mass-produced!

Those who have recently learned the nature of the statistical methods may be disappointed and even shocked that so little importance is given to these statistical tools in the foregoing analysis. Yet this is a considered judgment, and by one who has pioneered in the use of these same tools. In all too many instances, an admirable knowledge of the statistical tools is frustrated by lack of organization, or lack of quality-mindedness, or engineering inadequacy. Knowledge of the statistical tools is highly desirable, and probably necessary, but definitely not sufficient, by itself, to bring about substantial improvements in the handling of the quality function.

One more caution on the use of the statistical tools—look at it from the other fellow's viewpoint; how can **his** aspirations be advanced by his use of these tools, for such is his criterion. By the same token, the emphasis must be on **use** of these tools and not on their knowledge.

Seldom has human society adjusted to any deep and fundamental change without some false starts. The adjustments to the rise in precision may be no exception to this. There will be some overemphasis and some over-enthusiasm as people strive to find the correct solution. Those charged with carrying out the quality function have a responsibility to minimize this natural tendency to false starts by acquiring a broad understanding of the entire quality function before they undertake to decide on the adjustments they will make.

Fundamentals of Quality Control

LLOYD A. KNOWLER

CHAIRMAN, DEPARTMENT OF MATHEMATICS, STATE UNIVERSITY OF IOWA

I. SOME PRINCIPLES OF QUALITY CONTROL BY STATISTICAL METHODS: CLINIC 1

The application of statistical methods to the control of the quality of manufactured goods is becoming well known in industry. Many industrialists regard it as one of the most important of the recent developments. This is particularly true for many of the industries which were devoted to the manufacture of goods directly related to the war effort. These concerns had to manufacture goods hampered by lack of material and inadequate numbers of trained personnel, and they had to make the goods to meet close specifications without much loss of time. Professions other than engineering are also beginning to adopt the procedures. Excellent results have been reported in each of the following categories:

1. Improving the quality of inspected materials.
2. Improving the quality of the final product.
3. Economies in the use of labor and materials.
4. Decreasing rejects.
5. Decreasing inspection costs.
6. Improving producer-consumer relations.
7. Aiding in the conversion from the production of one type of product to another.

Many attempts have been made to give a short statement which expresses the idea of quality control by statistical methods. None of them has been entirely satisfactory because none has been broad enough to include the entire area and at the same time specific enough to give adequate meaning. However, one statement which approximates the desired result is: "Quality control by statistical

methods is a new approach to the quality problem that places decisions on a factual, statistical basis."[1]

Probably the phrase "quality control by statistical methods" is largely self-explanatory. Its meaning varies according to the industry in which it is applied and to its use on a project. The quality of a product starts with the design and specifications, but it is also affected by the materials used, by the production process, and by the inspection of the final product. Originally a great deal of interest was given to acceptance sampling —a phase which is still very important. In more recent years, however, the production process has received its share of attention, and at present considerable time is also being devoted to design and specifications. Perhaps it is possible to predict additional emphasis on research and development in the future.

One of the fundamental ideas of quality control by statistical methods is to undertake to build quality into the product by keeping the various steps of the process within control. That is, quality must be **BUILT** into a product: it cannot be **INSPECTED** into it. The value of having a uniformly good product is well known. What counts most to the consumer is not how good is the **average** quality produced by the company, but how good is **my** candy bar, or **my** pencil, or **my** pair of shoes.

Quality control methods are useful in aiding the maintenance of a desired quality level by providing a factual basis for evaluating what is being done in the plant and for setting specifications in a more scientific way. The methods may serve as an aid in the determination of the quality level which should be maintained. This quality level is first affected by inspecting the incoming materials, such as the corn which is made into syrup, or the peas which go into a can, or the milk which is bottled, and by keeping a continual check on vendors supplying them. Statistical tests are also used in the determination of the quality of material through an analysis of certain ingredients, the viscosity of a fluid, the temperature of a metal, or the silicon content of a bar.

In a food industry large savings may be effected through the analysis by statistical procedures of the actual weights of material put into a container. In a concern manufacturing optical lenses the procedures are of value in checking the grinding instruments. This checking may be the result of a single procedure such as keeping a chart in a suitable form of the breakage occurring at some assembly point. In the production process at a machine shop, interest may focus on pins of a certain length, bolts of a certain diameter, or gears of a certain dimension. Statistical procedures are desirable to aid in adjusting the various machines so as to maintain tolerances. Possibly an analysis of the shut down time of a machine is valuable. Often an analysis will reveal when a machine is about to cause trouble. Such an analysis has obvious predictive value. A commercial establishment may find it profitable to study the causes for absenteeism, or the cause contributing to a difference in performance at different times of the day. A change in lighting system is often worthwhile. The personal comfort of individual employees is important. Discomforts which were easily adjusted have been discovered through the analysis of control charts. For clerical operations, or in processes involving human operations, a study of the different types of errors may be valuable.[2]

The scientific methods of statistical quality control are being used in such industries as aircraft, candy, chemicals, clay products, drugs, electrical equipment, farm machinery, food, foundries, glass, mail order, metal working, optics, paper, plastics, radio equipment, rubber, feeds, seeds, small arms, steel, surgical dressings, telephone, textiles, and tools. **Fundamental principles are the same: applications vary.**

Two of the principles which underlie the theory of quality control are variation and measurement. No two things are exactly the same: there are differences between any two articles. These variations may be small, but they do exist. It is immaterial as to the refinement of the variations: the quality control procedures are similar. By studying the differences, progress can be measured. The measure may be the weight of a product, the number of errors made by an individual, the number of letters misfiled, the per cent of scrap, the number of defects found in final inspection of a finished product, the number of blowouts in a mile of insulated wire, per cent of germination of seed corn, the number of defective bricks or blocks in a quantity of building material, the number of sales in a certain area, the number of returns from a questionnaire, the number of inquiries because of a circular, the volume of business because of the distribution of catalogues, the number of pin holes in a paint job, the tension on a spring, or the number of thin spots in a sheet of paper.

It is known that a large number of causes contribute to the variation in quality from one unit of the product to another. If the cause contributing to the variation can be identified, it is called **an assignable cause.** One of the problems in quality control is to learn to find the assignable causes so that they can be eliminated or allowance made for them. Mathematical statisticians and industrial representatives have combined to develop sound statistical theory which has been perfected and simplified to such a degree that industry is making effective applications in the inspection of incoming material, in the location of trouble in the production process, and in warning of imminent trouble. All this helps to reach a verdict in the inspection of the final product and in advising when the production process should be changed. Needless to say, these benefits represent a substantial saving in labor and materials.

It is desirable to note that what is a finished product to one concern or one department may be raw material to another. Ten thousand pairs of shoes may represent the finished product to a shoe manufacturer, but they are raw material to a shoe store or to a mail order company. If some part of an engine, a tractor, a shell, a battery, or a pump is completed in one de-

1. **Quality Control**, Deere and Company, Chicago, Illinois, Fred J. Halton, Jr., Assistant to President, et al.

2. **An Adaptation of Statistical Quality Control at Aldens:** James M. Ballowe, Quality Control Report No. 7, Quality Control Program, Carnegie Institute of Technology for Office of Production Research and Development, War Production Board, Sept., 1945.

partment and sent to another for additional work, the finished product of the first department becomes raw material to the second. In fact, nearly all the materials received by a consumer are raw materials insofar as that particular person is concerned.

Much of the control achieved on the production line is based upon a control chart. The idea is relatively simple. In fact a control chart has been likened to a highway in that a highway of a certain width must be maintained to accommodate the necessities of driving vehicles. The width of the pavement necessary for a car is different from that needed for a span of mules hitched to a hay rack, although each width can probably be determined in a fairly accurate manner.

In order to see more specifically the relationship between a highway and a control chart consider Figure 1 and Figure 2 together with the diagram shown in Figure 3. It will be observed that the **pavement** corresponds to the **green** of the **safety** zone. Along either side of the pavement is a **shoulder** referred to as the **yellow** or **caution** zone, while beyond the shoulder is the **ditch** referred to as the **red** or **danger** zone.[3] The pavement or safety zone should be of a certain width in order to satisfy the needs. This width depends again on the vehicle or the mode of transportation. For economy it should be set so that one is safe to be upon the road. It is unnecessary that it be otherwise. In fact, width is determined by the vehicle and driver being used: that is, **by the process**. The edges of the pavement are represented by control limits. Should a wheel of the car get off the pavement (outside a control limit) then action should be taken in order to bring it back into control, or the result may be disastrous. The boundary between the shoulders and ditch represents the specification limits. It is necessary to keep individual parts within these limits in order to avoid the production of scrap. This can be done by keeping the process in control and by taking specific action when plottings occur outside the control limits.

3.The color scheme was worked out with the cooperation of E. L. Fay.

4.E. L. Fay, Chief Inspector, John Deere Tractor Co., Waterloo, Iowa.

Figure 1
PICTURE OF HIGHWAY

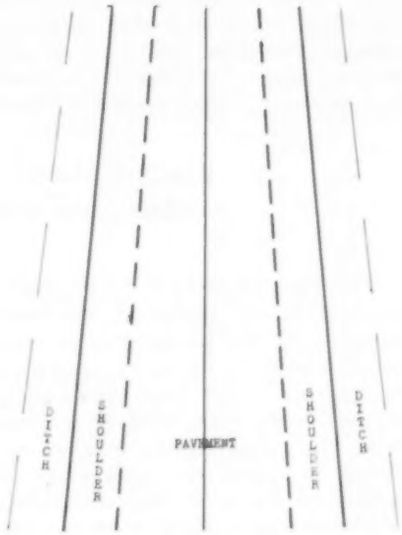

Figure 2
HIGHWAY DIAGRAM

In the beginning (and still too frequently) the procedures of quality control by statistical methods were regarded as applying only to inspection problems. They were thought of as related only to the acceptance or rejection of material purchased by the plant. This, it is now recognized, is but a small portion of the area for fruitful applications.

The individual who writes the specifications should know the capabilities of the machines and personnel as well as the quality of the material. He needs to know the variations of the process so as to set tolerances in an intelligent manner and so that they can be held economically. Management needs to know when it is economical to make a fundamental change in the process. Will the present equipment produce satisfactory material? Is it more economical to recondition old machines or should money be spent for new ones? Is it more economical to employ trained personnel for a particular job or to use that which exists? Probably breaking points at which the various economies are affected are more readily obtained by statistical procedures than by certain empirical processes or hunches which one often has concerning them. In addition, a study should be made

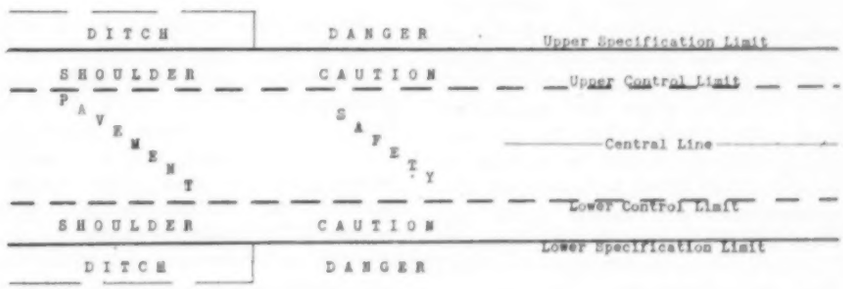

Figure 3: HIGHWAY LIKENED TO CONTROL CHART

The control chart is thus a **picture** or a **photograph**[4] of the process, and it should be placed near the machine or operation. The chart represents an advertisement[5] for the worker of what he is doing. It is easy to follow and relatively simple to interpret. Control chart techniques will be discussed in more detail in subsequent sections of this paper.

5.Wayne M. Biklen, Quality Control Engineer, W. A. Schaeffer Pen Company, Ft. Madison, Iowa.

to determine if wages are just at various points in the production line.

Many persons are interested in short runs, possibly a job shop operation. It is easy to recognize the value of statistical procedures in a long run where a number of similar articles are produced. The procedures are obviously of particular value to a company which must produce a large number of parts to close tolerances. But what is the application when there is a

small number of articles? At one time this thought was prevalent in each of the industries previously listed in the paper, but not at the present time. It is not essential that each piece be alike. In fact, no two pieces are ever exactly the same. Applications have been made where no two pieces were intended to be the same, where the production was but one item per week, and where only a few items were on one order. Such applications are especially valuable if a similar run will be made at a later time. One fact is often overlooked: the control chart on one machine or one operation is essentially the same as an application in a small concern, even though that one machine or one operation may be a part of a large unit. In fact, it might even be conceivable that statistical procedures would have a greater proportionate saving in a short run than in a long one.

In the development of a quality control program two important factors should be considered. First, **get started**, but do not go too fast. Many times management, upon reviewing the results of one or two installations, will request "three or four carloads" within a few days. This simply cannot be done. It takes time. It is even dangerous for an experienced quality control engineer familiar with installations to try to inaugurate a complete program overnight. Personnel must see the success of the plan and be carried along with it. In fact, it might even be suggested that current procedures be carried along simultaneously for at least a short time so as to be sure that the applications are being made as they should. The second important factor is to **understand the fundamental principles.** The people on the job or in the plant—the machine operators or the clerks involved—as well as management, should understand the fundamental ideas which are basic to the program. Action must be taken when the charts indicate the presence of an assignable cause.

Management is very much interested in the quality of the product under its supervision, and such interest is likely to be more intensive in the future. Very likely management will desire to have someone report directly to it concerning the quality of the work being done or the product being made by the process: it will be vitally interested in observing the progress being made. It recognizes that modern techniques of quality control by statistical methods are going to be a permanent development. Present procedures are being steadily improved as additional applications are made.

Many persons now recognize that there is little value in collecting data if it is not to be used. Much material has been collected and filed away in a desk drawer where it does no one any good. Mathematical statisticians realize that too many interpretations have been made from an incorrect analysis or from an analysis based upon a faulty collection or mistabulation of data. Many times an individual, in order to support a whim or a hunch, gathers data in such a way as to substantiate such whim or hunch, even though it may be necessary to disregard most of the data which fail to support his narrow view. A theory should be tested by sound statistical procedures—biased data should not be secured to support a whim. The collection, the tabulation, the analysis, and the interpretation of the data tie together, and when properly united are profitable to the company and all concerned.

II. DEMONSTRATION AND CONSTRUCTION OF AVERAGE AND RANGE CHARTS: CLINIC 6

Much of the gain through quality control by statistical methods arises from the production of material which conforms to specifications, rather than from attempting to sort good from bad at a later time. In other words, it is an attempt to control the production of goods at the time they are being made—at the machine when an operation is taking place. The behavior of the process includes all that goes with it: that is, men, machines, and materials.

Success has been achieved to a large extent by use of control charts which give the picture or photograph of the work as it is done. A control chart is relatively simple to construct, and it is easily interpreted by one who understands the fundamentals upon which it is based. These fundamentals are readily grasped by the personnel when presented to them clearly. One important type of control chart is referred to as the average ($\overline{X}$) and range (R) chart. This is really two charts which are usually constructed simultaneously.

As an example, assume the production of pins which have specifications set at 6.0000" $\pm$ .0005" in length. It is known that it is impossible to have each pin exactly 6.0000" in length, hence the condition that each acceptable pin shall be between 5.9995" and 6.0005".

The problem might as well have been to determine the smallest average weight of food necessary to put into containers so as to have the net weight of the contents to be one pound, or to determine the time necessary to cook a product so as to obtain a certain viscosity, or the minimum length of cloth necessary to meet a standard after allowance for shrinkage, or the deviations to be permitted from a standard budget without making a special investigation, or to select from a battery of machines the particular one which produces bad material, or to study the behavior of an automatic screw machine making small parts. Applications are numerous: the fundamental principles and particular procedure which follow are the same for each of them.

Suppose the process—men, machine, material—has been producing pins which have fallen into a tote box as they have been made, or possibly they have been kicked out on a belt line. Take a pin at random from the tote box or belt line. Upon measurement its length is found to be 6.0002". A tendency might exist to alter the set-up to produce pins which are .0002" shorter. Then another pin is measured and found to be 5.9997"—a second adjustment is made to make them .0003" longer. Another pin is measured and discovered to be 6.0002". Apparently the machine is back to the initial setting—actually the process has been adjusted so as to make pins .0001" longer

than at first. Another adjustment and the pin measures 5.9999". Another adjustment and the result is 6.0000". This procedure could be continued as long as the machine is operating. The tendency for some operators to make numerous adjustments is well known. On the other hand, some operators hesitate to make adjustments. Does the control chart offer a guide to the elimination of this operator inconsistency?

The machine should be allowed to operate long enough to determine the actual variation which exists, and to discover the setting which enables the machine to make the greatest number of satisfactory pins. The existence of variation is understood; the problem is to find out the amount of variation which is to be expected, and to determine if the specifications can be met. To a large extent, these objectives can be attained by taking small random samples at regular intervals, examining them carefully, and putting the results on a control chart.

Consider the five measurements referred to above as though no adjustments had been made. The lengths were 6.0002", 5.9999", 6.0001", 6.0000" and 6.0000". Their sum is 30,0002". This total divided by 5 gives 6.00004" for the **average** ($\overline{X}$) length of the pins. Not only is this average length valuable, but also the amount of deviation between the largest and smallest is desired. The longest pin was 6.0002"; the shortest was 5.9999". The difference between these two lengths, .0003", is referred to as the **range** (R).

A little later, maybe ten minutes, thirty minutes, or possibly an hour, according to the amount of production, a second sample of five pins is taken at random from the production during the period. Suppose the five measurements to be 6.0000", 6.0000", 5.9997", 6.0002" and 5.9997". For these five, $\overline{X}$ = 5.99992". The range in this case, being the difference between the largest and the smallest, is R = .0005" - - the difference between 6.0002" and 5.9997".

To save a great deal of calculation and paper work, and to reduce the error hazard as well as the time involved, a computation shortcut should be introduced. This consists in considering the deviations from 6.0000" instead of the actual length. It will be useful to have a form to use in recording the measurements. This form should be self-explanatory, and can be constructed so as to satisfy the conditions of the problem at hand. The accompanying "Midwest Quality Control Data Sheet" is suggestive. In order to save space, the record of the measurements will be continued in the form of Table I.

Reconsidering the first example then, the record in units of ten thousandths of an inch would be: 2, -1, 1, 0, 0. The five measurements total 2, which when divided by 5 gives an average ($\overline{X}$) of 0.4. The range (R), being the difference between the largest and smallest, is 3. To see why negative numbers are handled this way, we might consider the temperature as being -1 in the morning and 2 at noon, during which time it has warmed up 3 degrees.

MIDWEST QUALITY CONTROL DATA SHEET

Product ..... Date .....
Characteristic ..... Number in Sample .....
Unit of Measurement ..... Machine .....
Specification ..... Operator .....
Inspector .....

Sample	1	2	3	4	5	6	7	8	9
Time									
Individual Values	+2	0	+3	+1	−1	−1	0	0	+2
	−1	0	+1	−3	0	0	0	+2	0
	+1	−3	+4	0	+1	−1	+3	−2	0
	0	+2	−2	+1	0	−2	−1	−3	+1
	0	−3	−1	−1	+1	−3	+3	0	+1
Total	2	−4	+5	−2	+1	−7	+5	−3	+4
$\overline{X}$	+.4	−.8	+1.0	−.4	+.2	−1.4	+1.0	−.6	+.8
R	3	5	6	4	2	3	4	5	2

Sample	10	11	12	13	14	15	16	17	18
Time									
Individual Values	0	+1	0	−2	+2	+2	0	0	−2
	+3	−2	0	−3	−1	−2	+4	0	−1
	+2	+1	−2	+2	0	+1	−4	−1	+2
	+1	+1	−2	−1	−2	−1	0	0	−1
	+1	+3	0	−5	−1	0	+3	+2	0
Total	+7	+4	−4	−9	−2	0	+3	+1	−2
$\overline{X}$	+1.4	+.8	−.8	−1.8	−.4	0	+.6	+.2	−.4
R	3	5	2	7	4	4	8	3	4

Sample	19	20	21	22	23	24	25
Time							
Individual Values	−2	+2	0	0	−1	0	+1
	0	−2	−1	+2	−1	+1	−1
	−1	−1	−1	+1	+2	+1	−4
	−1	+2	−1	+1	−1	−3	−1
	0	−1	+1	+1	+1	−2	+1
Total	−4	0	−2	+5	0	−3	−4
$\overline{X}$	−.8	0	−.4	+1.0	0	−.6	−.8
R	2	4	2	2	3	4	5

Notes: .....

TABLE I

Sample Number	Measurements of each of five items in sample					Sample Average	Sample Range
26	3	0	0	1	−1	0.6	4
27	2	−1	2	2	1	1.2	3
28	4	2	1	3	1	2.2	3
29	1	3	−1	0	−2	0.2	5
30	2	1	1	2	1	1.4	1
31	2	3	−2	3	2	1.6	5
32	2	−2	−1	0	1	0.0	4
33	2	0	1	0	1	0.8	2
34	1	−1	2	1	2	1.0	3
35	2	−1	5	0	2	1.6	6
36	−2	1	5	−3	−1	0.0	8
37	0	3	3	−1	1	1.2	4
38	−5	−5	5	2	−3	−1.2	10
39	0	−4	−6	2	−2	−2.0	8
40	−3	−1	0	7	4	1.4	10
41	−4	−3	−1	0	2	−1.2	6
42	2	4	−4	0	2	0.8	8
43	6	0	4	0	5	3.0	6
44	−5	3	8	7	−5	1.0	16
45	−1	−6	−1	1	−4	−2.2	7
46	2	−2	−1	1	5	1.0	7
47	5	5	0	0	2	2.4	5
48	7	2	−5	−4	−2	−0.4	12
49	4	−2	−3	1	7	1.4	10
50	−4	−2	4	5	0	0.6	9

There is no profit in collecting data that are not going to be of immediate use. The information collected becomes meaningful when put on a chart before the operator and at the machine—it is useless when filed away in a desk drawer to be observed next week or not at all. Accordingly, the data are transferred at once to a control chart. Plottings of the individual values are as shown on Figure 4 corresponding to sample number 1. The plottings of the average $\overline{X}=0.4$ and the range $R=3$ are represented as sample number 1 in Figure 5. It will be observed that the plotting in Figure 5 corresponds to the encircled point in Figure 4. That is, a comparison of Figure 4 and Figure 5 gives a relationship between the individual values and the average value for sample numbers 1-10.

The plottings of $\overline{X}=0.4$ and $R=3$ show that the average is slightly above zero, and give an idea of the spread. In a similar manner sample number 2 is plotted. Although no change has been made in the process, the average is seen to be a little less than zero and the spread somewhat larger. This procedure is repeated for 25 samples of 5 each.

The chart in Figure 5 indicates that the average for these 25 samples is about right. It also shows that the process is in control, since all of the averages fall within the control limits which will be explained presently. This means two things; that the material which has not been inspected is consistent with the inspected samples, and that the process can be expected to produce material in the future which is consistent with the inspected samples.

It is very dangerous to draw inferences from data without making a statistical analysis. Often what looks to be true is deceiving. A critical examination of these data involves determining the center of the distribution and the width of the so-called highway necessary to enclose practically all points, provided no assignable cause is operating. Adding the 25 averages together, gives $\Sigma\overline{X}=-1.8$, which when divided by 25 gives a grand average of $\overline{\overline{X}}=-.072$. This represents the center line on the average chart, and is indicated by a heavy line. It is rather standard procedure to draw this line in red. Similarly, the sum of the range column for the 25 items is $\Sigma R=96$, which when divided by 25 gives an average range of $\overline{R}=3.84$; this also may be indicated on the chart by a heavy red line.

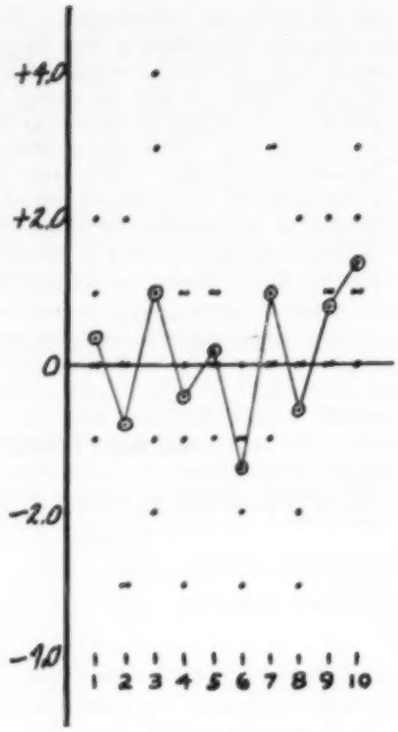

Figure 4
INDIVIDUAL PIN LENGTHS

So much for the center line, or the middle of the highway. The next step is to close up the edges of the pavement enclosing the safety zone. Mathematical statisticians[6] have developed formulas for this purpose. These formulas are relatively simple, although the theory behind some of them is not too elementary. Reference to the American War Standard Z1.3-1942, **Control Chart Method of Controlling Quality During Production,**[7] provides the formulas: $\overline{\overline{X}}\pm A_2\overline{R}$ for the upper and lower control limits for the average chart, and $D_4\overline{R}$, $D_3\overline{R}$ for the upper and lower control limits for the range chart.

From previous work, $\overline{\overline{X}}=0.072$ and $\overline{R}=3.84$. The Z1.3 Standard gives $A_2=0.577$, $D_4=2.114$, and $D_3=0$ for samples of 5 items. Substituting in the formula for the averages gives $\overline{\overline{X}}\pm A_2\overline{R}=-0.072\pm(0.577)\ (3.84)=$

2.14 U.C.L.-Upper Control Limit
-2.29 L.C.L.-Lower Control Limit,

and for the ranges

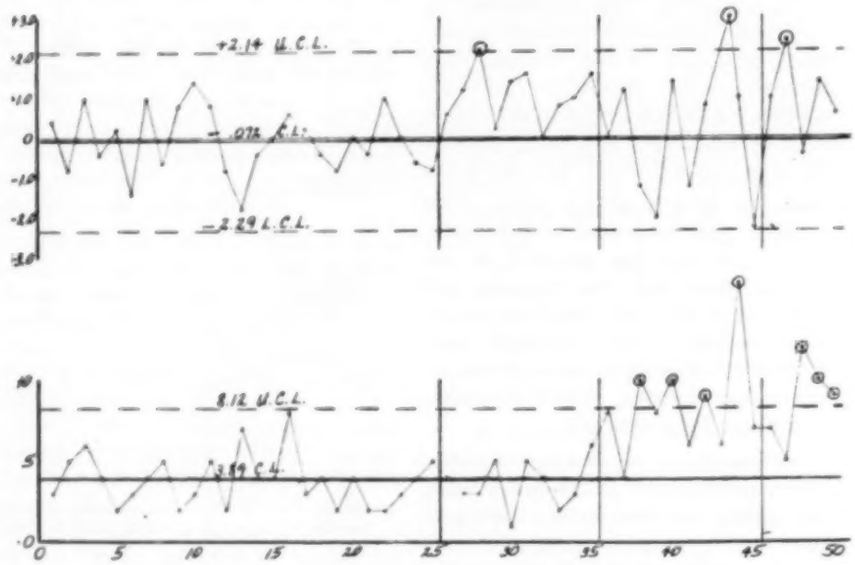

Figure 5: AVERAGE AND RANGE CONTROL CHARTS FOR PIN LENGTH

$D_4\overline{R}=(2.114)\ (3.84)=8.12$ U.C.L.-Upper Control Limit

6.Luella R. Pollock has collected the development of the formulas in the M. S. Thesis "Some Statistical Developments of Quality Control Charts," University of Iowa, April, 1945.

7.May be purchased by writing American Standards Association, 70 East 45th Street, New York, 17, N. Y., Price seventy-five cents.

$D_3\bar{R} = (0)\ (3.84) \quad = 0.00$ L.C.L
Lower Control Limit.

Drawing lines (usually heavy broken red lines) on the chart at these values, confirms a previous statement that the process is in control: that is, it is consistent: all of the observed variability can be ascribed to a constant system of chance causes. Since the process is in control, it can be inferred that this condition will continue until an assignable cause (or causes) enters the process.

The next step is to determine whether or not the process makes material that will meet the specifications of 6.0000" ± .0005". To do this, a test formula is available which quite often is not understood or is not used to full advantage. The test formula gives the spread or dispersion in the individual items, pieces, or separate units of work being produced. The particular test formula to be used is $\sigma'_x = \bar{R}/d_2$ where σ'_x is read "sigma-prime of x", or simply "sigma-prime." Sigma-prime may be thought of as a unit of measure such that when the process is in control practically all the individual pieces will be within a distance of three times this value ($3\sigma'_x$) from the grand average $\bar{\bar{X}}$. That is, practically no pins will be longer than $\bar{\bar{X}} + 3\sigma'_x$ inches, and practically none will be shorter than $\bar{\bar{X}} - 3\sigma'_x$ inches.

Reference to the Z1.3 Standard shows that $d_2 = 2.326$ for samples of size 5. For the particular example

$$\sigma'_x = \frac{\bar{R}}{d_2} = \frac{3.84}{2.326} = 1.651,$$

$$\bar{\bar{X}} \pm 3\sigma'_x = -0.072 \pm 3\ (1.651) = 4.881 \text{ and } -5.025$$

That is, practically all of the pins will be between 6.0000" − .00050" = 5.9995" and 6.0000" + .00049" = 6.0005", as required by the specifications.

A further analysis of the control chart for averages reveals that should the center line shift, the lengths of the individual pins would have shifted, and the process would be producing some material which would not meet specifications, unless, of course, there had been a compensating decrease in the average range.

Since the process is in control at a satisfactory level (meeting specifications), we can extend the control limits for the next period of operation and expect the plottings to stay within them unless an assignable cause enters. Should an assignable cause exist, then some plottings will probably fall beyond the control limits, or the center line will shift. A shift of the center line will be suspected if points tend to hover on one side of it.

In Figure 5 the control limits based upon samples 1 to 25 have been extended on through samples 25 to 60. For plottings 26 through 35 the range seems to be about the same. The average, however, seems to have shifted upward. In fact, the third sample point, number 28, falls just outside a control limit. Maybe this performance will still be consistent, but if so, it is consistent at an undesirable level —sooner or later scrap will be produced. In this particular example it happens that the mean was shifted .0001", and indeed it showed on the control chart very early. The original spread remained unchanged. This too is indicated on the chart.

For plottings 36 through 45 there was quite a shift in the range chart. In fact, each of the plottings is above the central line, and four of the ten plottings are above the upper control limit. The average chart shows that the plottings jumped about a great deal, and one is even above the upper control limit. There is a tendency, however, for the averages to hover about zero. In this particular series the average was zero, but the variation or spread was increased as is shown on the chart. When such a condition exists it is expected, from a theoretical point of view, that plottings will be outside of the control limits on both the average and the range charts. This demonstration turned out to confirm expectation.

Consider sample numbers 46 through 50 wherein the center has been shifted .0001" and the spread remains large. Although only five plottings are made, the center has shifted on the chart and the range has remained large. **In other words, the control chart shows through this entire demonstration of 50 plottings exactly what was happening when it happened. It gave warning of trouble early in the game.**

In Figure 6, is shown the relation between the distribution of averages, control limits based on averages, the distribution of individual items, and the possibility of meeting specifications. Without undue refinements, the broken curve in Figure 6 is the theoretical representation of the distribution of the lengths of the individual pins used in the example. The heavy curve represents the theoretical distribution of averages, each based on a random sample of five pins. The heavy horizontal line represents the center (or average) of each distribution, the broken horizontal lines represent the upper and lower control limits of the average chart, and the arrows point to the values between which practically all of the individual pin-lengths should fall.

A comparison of the actual values based upon only 25 plottings and the theoretical values may be of some interest:

	Actual	Theoretical
$\bar{\bar{X}}$	-0.072	0.00
Upper Control Limit	2.14	2.30
Lower Control Limit	-2.29	-2.30
σ_x	1.651	1.715

Although one should be reluctant to accept much less than 20 plottings to characterize a process (10 plottings are usually considered to be a dead minimum), the following comparisons are given:

Samples 26-35 (10 plottings)	Actual	Theoretical
$\bar{\bar{X}}$	1.06	1.00
σ_x	1.55	1.715

Samples 36-45 (10 plottings)	Actual	Theoretical
$\bar{\bar{X}}$	0.08	0.00
σ_x	3.57	3.47

Samples 46-50 (5 plottings)	Actual	Theoretical
$\bar{\bar{X}}$	1.00	1.00
σ_x	3.70	3.47

A question might be raised as to the action to be taken when the individual values do not fall as indicated in Figure 6. Two courses of action may be taken. First, one could study the frequency distribution of the individuals by taking a random sample of some 50 or 100 items. By so doing, one

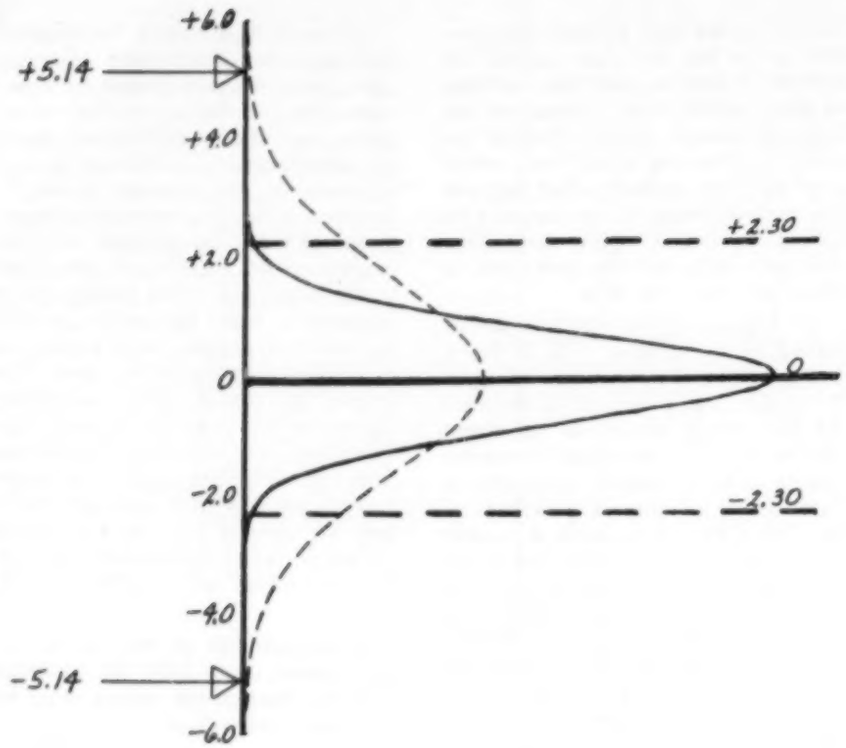

Figure 6: THEORETICAL DISTRIBUTION CURVES FOR AN AVERAGES CHART

will often discover that no great difference exists between theory and observations. If a great difference does exist, then, of course, one can predict how much rework and/or how much scrap to expect. If rework must be done, then it must be recognized that 100 per cent inspection is necessary, and that the cost must be borne. This would have to be balanced against making scrap. It is often more economical to make a small amount of scrap than to have 100 per cent inspection, especially on small items which are inexpensive.

A second course of action would be to consider the readjustment of specifications. Often they can be altered without any functional difficulty in using the part. Then the standard procedures can be used quite effectively.

In summary, the following points should be noted: (1) the control limits are set by the process itself —one should look for an assignable cause by focusing attention on the process when plottings fall outside these control limits; (2) when control is established it is possible to predict the future behavior of the process; (3) it is desirable to make a statistical analysis whenever a process has been changed; (4) control charts are useful in maintaining control after it has been attained; (5) a control chart is simple to construct and the story it tells is direct; (6) a control chart by itself will not produce good material, but it aids in the more rapid production of good material by giving a picture of the process when it is needed.

III. AN APPLICATION OF AVERAGE AND RANGE CHARTS: CLINIC 11

As a particular example of average and range charts, consider the following data which, as indicated, refers to a fuse that is to blow within 150 seconds. The specific data given in the Control Chart Data Sheet on page 15 are self-explanatory.

In order to save space, the averages and ranges of sample numbers 1-12 together with the corresponding values for the next thirteen samples, numbered 13-25, are tabulated in Table II.

As in the previous demonstration, the averages and ranges are plotted on the following charts referred to as Figure 7.

The immediate problem is to determine whether or not the process indicated in Figure 7 is within control. As before a preliminary calculation of the control limits is based upon all data. The computations are,

$\overline{\overline{X}} = \frac{1848.0}{25} = 73.9$ Central Line,

$\overline{R} = \frac{1503}{25} = 60.1$ Central Line,

$\overline{\overline{X}} \pm A_2\overline{R} = 73.9 \pm (0.577)(60.1)$
$= 108.6$ U.C.L. and 39.2 L.C.L. for averages,

$D_4\overline{R} = (2.114)(60.1) = 127.1$
U.C.L. for ranges.

$D_3\overline{R} = (0)(60.1) = 0$
L.C.L. for ranges.

The control charts for the preliminary data show a decided lack of control of $\overline{X}$, with extremely high values in the period for sample numbers 10-14, and scattered instances of lack of control of $\overline{X}$ and R for sample numbers 8, 21, and 22. The high level of $\overline{X}$ during the period for sample numbers 10-14 was definitely attributed to a faulty lot of raw material, which was thereupon withdrawn from the production line and replaced by a new lot. There were no known reasons for the lack of control indicated by sample numbers 8, 21, and 22. Sample numbers 10-14, only, were therefore disregarded, and new values for control limits were computed for the remaining samples.

In this work interest centers in knowing what the process does with the men, machine and materials being used. Consequently no data or plottings should be excluded unless an assignable cause has been discovered and eliminated. Since the faulty material was withdrawn from the process, but no known reasons for lack of control in samples 8, 21, and 22 were discovered, it is standard practice to disregard only sample numbers 10-14 in calculating the new control limits.

CONTROL CHART DATA SHEET

PRODUCT .....Fuse..... PRODUCTION ORDER NO. .....000.....
CHARCTERISTIC .....Time of Blow..... SAMPLE .....5..... PER .....Hour.....
UNIT OF MEASUREMENT .....Seconds..... DATE .....Nov. 3-4, 1941.....
SPECIFIED LIMITS .....150 sec. Max..... RECORDED BY .....

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Time	AM 8:35	9:25	10:30	11:00	PM 1.00	1:50	3:05	4:00	AM 8:30	9:25	10:30	11:35
Observed Value, X (Individual values)	42	42	9	36	42	51	60	18	15	69	64	61
	65	45	24	54	51	74	60	20	30	109	91	78
	75	68	80	69	57	75	72	27	39	113	93	94
	78	72	81	77	59	78	95	42	62	118	109	109
	87	90	81	84	78	132	138	60	84	153	112	136
Total	347	317	275	320	287	410	425	167	230	562	469	478
Average, $\bar{X}$	69.4	63.4	55.0	64.0	57.4	82.0	85.0	33.4	46.0	112.4	93.8	95.6
Range, R	45	48	72	48	36	81	78	42	69	84	48	75

Sample Number 10: 1 fuse exceeds maximum limit, 35 additional fuses tested.
Data recorded on supplementary data sheet.
Adapted from "Control Chart Method of Controlling Quality During Production," p. 23, American Standards Association.

Table II. SUMMARY AND CONTINUATION

Sample Number	Average $\bar{X}$	Range R	Sample Number	Average $\bar{X}$	Range R
1	69.4	45	16	80.8	45
2	63.4	48	17	71.8	57
3	55.0	72	18	53.2	75
4	64.0	48	19	74.8	48
5	57.4	36	20	59.2	63
6	82.0	81	21	65.8	129
7	85.0	78	22	109.6	42
8	33.4	42	23	44.2	51
9	46.0	69	24	73.6	51
10	112.4	84	25	51.4	27
11	93.8	48	Total	1848.0	1503
12	95.6	75			
13	117.8	51			
14	113.6	84			
15	74.8	54			

Calculation of control limits with faulty material withdrawn from the process yields:

$\bar{\bar{X}} = \frac{1314.8}{20} = 65.7$ C.L. for averages,

$\bar{R} = \frac{1161}{20} = 58.0$ C.L. for ranges,

$\bar{\bar{X}} \pm A_2\bar{R} = 65.7 \pm (0.577)(58.0) = 99.2$ U.C.L. and 32.2 L.C.L. for averages,

$D_4\bar{R} = (2.114)(58.0) = 122.6$ U.C.L. for ranges.

$D_3\bar{R} = (0)(58.0) = 0.0$ L.C.L. for ranges.

The second problem, and usually an important one, is to test to determine if the present process will meet specifications, which is done as follows:

$$\sigma'_x = \frac{\bar{R}}{d_2} = \frac{58.0}{2.326} = 24.9,$$

$$\bar{\bar{X}} + 3\sigma'_x = 65.7 + 3(24.9) = 140.4 \text{ seconds.}$$

Since 140.4 seconds is less than the specified maximum of 150 seconds,

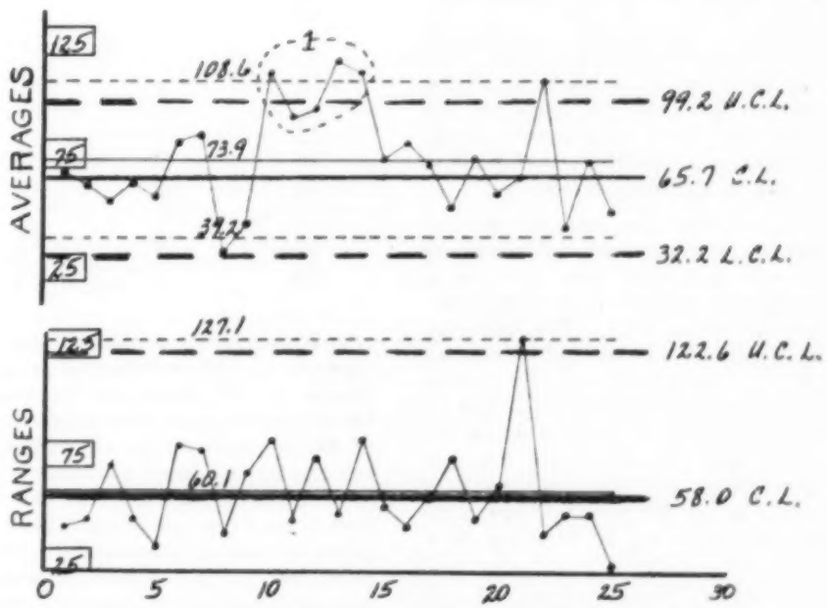

Figure 7: CONTROL CHARTS FOR BLOWING TIME OF A FUSE

the process is satisfactory, and the new values are adopted for use in the immediate future.[8]

It is probably unnecessary to present the exact details, but by a process similar to the above it is possible to make a great number of applications of which the following are suggestive: weight of a fluid in a container; life of electric light bulbs or vacuum tubes; weight of food in a package; results of chemical analysis of a product; moisture content of paper or rubber; velocity of a projectile; variation in deviations from the standard in cutting bolts of cloth; inside diameter of a bore; outside diameter of a bolt or piston; thickness of a steel plate; weight of a certain quantity of cloth; deviations from standards in budgetary control; number of absentees; weight of coating in a manufacturing process; quantity of fluid in a container; traffic or accident rates.

The approach to the problem, and the test to determine whether or not specifications are met, is the same in each of the examples cited. Additional applications are being made as more individuals are being trained in the work. It is largely a matter of understanding the fundamental principles and making the applications to the products in one's own plant or industry.

IV. INTRODUCTION TO FRACTION DEFECTIVE CHART: CLINIC 16

A second type of chart which has been used a great deal to good advantage is the fraction defective chart, often referred to as the p-chart. It is likely that a large amount of data is available in most plants which could be advantageously displayed on such a chart. It is useful not only on production but also in connection with the inspection of incoming materials: that is, acceptance sampling.

An item or unit is considered to be defective if it contains one or more defects with regard to the quality characteristic measured or under consideration. The fraction defective, p, is the ratio of the number of defective units to the total number of units under consideration—it is sometimes referred to as the proportion defective.

As an example, consider the behavior of the results of sampling by taking lots of size 50 from a process controlled at 4 per cent defective: $p' = 0.04$. The variability pattern of a controlled process can be demonstrated by taking samples at random from a box of beads which is 4 per cent defective. This might well represent the consideration of the number of scratches on 50 pens, or the number of burrs on 50 bushing nuts, or the number of absentees per 50 persons, or the number of breakdowns per 50 hours, or the number of defective condensers per box of 50, or the number of defective motors for a day's production of 50. Other charts such as the np and c-chart are also applicable to some of these examples. However, the p-chart is also appropriate, and is the one discussed here.

The first sample of 50 beads, contains two defective ones. The sample is 4 per cent defective: i.e., $p = 0.04$ in this case. A second sample of 50 contains one bad bead which represents 2 per cent defective, or $p = 0.02$. This procedure is continued for various combinations of sample sizes with the results as tabulated in Table III.

The values of p determined by the data in Table III are put on a control chart as indicated by Figure 8, which refers to samples of size 50, and Figure 9, which refers to samples of size 100. In practice, as with all control charts, these plottings are made as the values are known—the chart is kept up to date so management or those interested can take appropriate action immediately.

The results shown by Figure 8 for samples 1-25 will be examined more critically. The total number of defectives found in the 25 samples is 49. The central line, $\bar{p}$, is the ratio of the number of defective items found to the total number of items examined, thus,

$$\bar{p} = \frac{49}{(25)(50)} = \frac{49}{1250}$$

$= 0.0392$ or 3.92 per cent.

As usual, a heavy red line is drawn on the control chart at $\bar{p} = 0.0392$. It will be observed that the plottings tend to balance about this central line.

TABLE III

Sample Number	Number of Defectives in a Sample of Size		Sample Number	Number of Defectives in a Sample of Size	
	50	100		50	100
1	2	3	21	1	3
2	1	1	22	1	4
3	2	4	23	4	6
4	0	4	24	2	4
5	2	4	25	2	3
6	3	6	26	4	5
7	4	5	27	1	4
8	2	5	28	3	7
9	0	2	29	3	6
10	3	4	30	2	5
11	0	3	31	3	5
12	1	4	32	6	6
13	2	4	33	2	4
14	2	3	34	3	9
15	3	5	35	2	6
16	5	8	36	3	4
17	1	2	37	1	3
18	2	3	38	0	1
19	3	5	39	2	3
20	1	4	40	0	1

(8) The data for this example and much of the approach to its solution has been taken, by permission, from The American Standards Z1.3-1942 manual referred to in II above.

One might infer from the figure that a great deal of jumping around is taking place. It might even be inferred that sample number 16 was unusual. Before arriving at any conclusion the limits of chance variability must be investigated. For this type of chart, the control limits are given by the formula,

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

where n represents the number of observations in each sample—the sample size. Substitution in the formula, gives

$$.0392 \pm 3\sqrt{\frac{(.0392)(.9608)}{50}} \quad \begin{matrix} .1215 \text{ U.C.L.} \\ 0 \text{ L.C.L.} \end{matrix}$$

The lower control limit is taken as zero since it is impossible to have less than 0 per cent defective. When the L.C.L. = 0, it is often not represented on the chart. A heavy broken red line is drawn at U.C.L. = 0.1215.

It will be observed that each of the plottings fall within the control limits and in about the proportion that would be expected should a curve, similar to that of Figure 6, be superimposed upon the chart. In other words, the control chart indicates that the process is in control at approximately the 4 per cent level. If this process is satisfactory, the limits are extended and used as standard values. Attention should be focused on the process with the expectation of taking appropriate action should a plotting fall outside the limits, or if a shift in the process seems to have occurred. This shift might be observed either through a change in the central line or by an unusual distribution because of a run or of a concentration of plottings. Two controls are given on the average and range charts — **average** and **range.** Similarly, there are two controls in the p-chart: the **central line** and the **control limits.**

It will be observed that plottings for samples 26-30 are still within the control limits, although one might suspect a slight shift in the central line. One might suspect a greater shift in considering the representation of samples 31-35, since each of the plottings falls above the central line. These suspicions are justified in this demonstration because the process was altered so that the box had 5 per cent defective beads during the drawing of samples 26-30, and 6 per cent defective beads during the drawing of samples 31-35. Also, the apparent lowering of the central line for samples 36-40 resulted from changing the per cent defective to 3 per cent during this period.

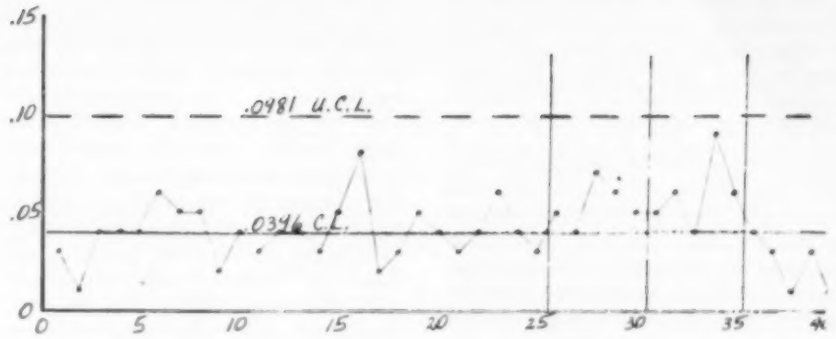

Figure 8: p-CHART FOR TABLE III, n = 50

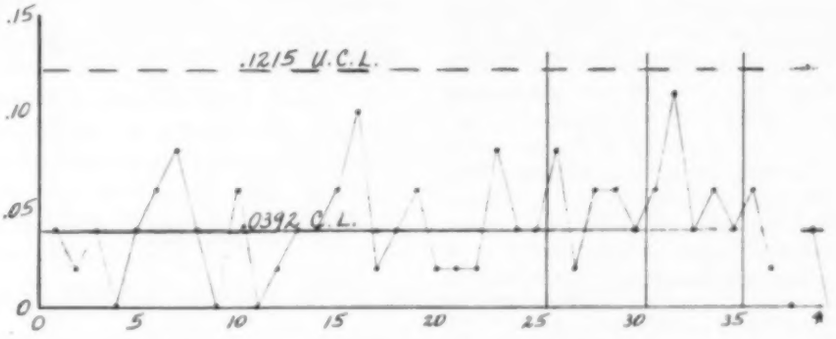

Figure 9: p-CHART FOR TABLE III, n = 100

A study of the control chart immediately tells one what has been taking place through the entire study far better than memory or a mere examination of the figures on the record sheet. Furthermore, the **central line** and the **upper control limit** provide a simple and reliable way of knowing when and if action should be taken, and also suggests the type of action to be taken. If a plotting falls outside the control limits for no apparent reason, it is probably desirable to look for an assignable cause and possibly eliminate it. If the plottings indicate the process is in control but at an unsatisfactory level, it is probably desirable to focus attention on the process with the expectation of making a fundamental change. This fundamental change may be an overall change or a breakdown of the component parts and a change in any one of them. The change may refer to men, machine, or material. Often the presence of the control chart itself will induce the necessary change.

In order to study the effects on such a chart when the sample size is changed to 100, Figure 9 has been constructed for the same processes and for the same number of samples. It will be observed that the central line agrees very closely with that in Figure 8. However, the value of the upper control limit is less since the amount of variation in the proportion defective is less for large samples than for small ones.

Probably the difference in the variation expected can be more readily understood by the consideration of taking samples of size one. An item is either good or bad. It is either zero per cent defective or 100 per cent defective. Samples of two may have either 0, 1 or 2 defectives, and the variation is either 0, 50, or 100 per cent: that is, from 0 to 100. On the other hand, in taking samples of say 10,000 from a very large 4 per cent defective lot, the probability

of obtaining 10,000 bad pieces is infinitesimal: that is, the number of defectives increases as the sample size gets larger, but the variation in the per cent of defectives becomes smaller.

It is important to recognize that with the p-chart, as well as with the others, the **control limits are set by the** process; whereas the **specifications as to allowable fraction defective are set by the engineer or by the individual in charge of the operation** upon consultation, perhaps, with management.

It is necessary to check the process against specifications. At one time the customary reaction was to demand no defectives, that is, to insist that the central line be reduced to zero. If the process is in control, and consistent, this demand would mean a change in the process—an expense would probably be involved. The expense might well be prohibitive. Again, an even worse condition might exist through a tendency actually to suppress some of the records so as to have a nice looking control chart. One must be sure the samples are taken in a random manner, inspections carefully made, and the data accurately and completely recorded. Then the control chart will tell what is being done—it will be valuable.

The p-chart has a great number of applications. It is ofen referred to as a management chart. It has been used with a great deal of success when applied to human operations.[9] When thoroughly understood, it is a very useful tool. In acceptance sampling, it has been found useful to plot the results from different vendors on the same chart. If copies of the charts are sent to the various suppliers, it may well be that the one submitting material of a poor quality will take appropriate action to remedy his manufacturing process. This type of application has been made, and has paid the consumer well.

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(9) James M. Ballowe, **How Will Quality Control Reduce Costs?**, Production Series Number 162, American Management Association, New York 18, New York, October, 1945. Also, see reference to Ballowe in 1 above.

NOTICE

The next report of the Midwest Quality Control Conference will appear in the September issue. Additional copies of this issue and the May issue can be obtained at a price of $1.00 each. The complete Conference report will be available at a price of $4.00. Requests for individual copies or for reservation of complete sets should be sent to Martin A. Brumbaugh, Crosby Hall, University of Buffalo, Buffalo 14. Payment should accompany orders for individual copies. In placing orders for the complete report, please give mailing address so that we can send bill when the set is ready, either in December, 1946 or January, 1947.

Tables to Facilitate Computation of Sampling Limits of s and Fiducial Limits of Sigma

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In constructing control charts, control limits are often placed at distances of three standard deviations, or three standard errors, above and below the central line, the central line being an arithmetic mean (actual or modified) of values that have previously been plotted. For items and means this pro-

cedure is fairly satisfactory since, if the process is in control and correct values are used for the mean and standard deviation of the population, 135 in 100,000 of the items and means tend to fall above the upper control limit, and a like number below the lower control limit.

The distribution of s (the standard deviation of a sample) around the population value σ is positively skewed, especially for very small samples such as are often used with control charts; and if the control limits are located at $\bar{s} \pm 3\sigma_s$ more than .00135 of the standard deviations will fall above the upper control limit, while less than .00135 of the standard deviations will fall below the lower control limit. This discrepancy becomes greater as the sample size becomes smaller, and when N is 5 or smaller $\bar{s} - 3\sigma_s$ is negative. For such cases the lower control limit is conventionally taken as zero.

Table 1 permits one to locate control limits so that a specified proportion of values should fall above the upper control limit, and a specified proportion below the lower control limit. These proportions need not be the same, since it may be more important to avoid a change in the cause system that makes the product less uniform than it is to seek the cause of a change in the cause system that makes the product more uniform. A table similar to the present one, for upper and lower probability points of .001 and .005 only, and for sample sizes from 2 to 15 inclusive, is published as Appendix 2 in American Standards Association, **Control Chart Method of Controlling Quality During Production**, Z1.3 — 1942.

As an illustration of the method of using Table 1 suppose that σ = .025" and we wish to determine control limits for samples of 10 so that 998 out of 1,000 sample standard deviations should fall inside the control limits, 1 out of 1,000 falling outside the limits on each side. Entering Table 1 at N = 10, we find for the lower .001 point a value of s/σ = .339, and for the upper .001 point a value of s/σ = 1.670. The control limits therefore are

Upper: $s = 1.670\sigma = 1.670 \times .025" = .042"$;

Lower: $s = .339\sigma = .339 \times .025" = .008"$.

Other uses of this table are apparent. It can be used to test whether the output of a new method of production is more uniform than standard. If the quality of a bad lot is defined in terms of uniformity, one can determine the standard deviation of a sample of size N such that if all lots of that standard deviation or less are accepted, not more than a specified proportion of bad lots will be accepted. Or, if an acceptance value for the standard deviation is specified, the sample size necessary to provide the desired assurance against accepting a bad lot can be ascertained. Still another use is the determination of the fiducial or confidence limits of σ for a given sample value s. The computation of these limits is somewhat simplified, however, by the use of Table 2, which can be derived directly from Table 1 by recording the reciprocals of the numbers in each pair of columns with columns of numbers reversed. A similar table for the .90 and .98 limits only and for N ranging from 5 to 30 appears in E. S. Pearson, **The Application of Statistical Methods to Industrial Standardization and Quality Control**, p. 69. London: British Standards Institution, 1935.

Suppose that s = 15 pounds, N = 25, and the .99 fiducial limits of σ are desired. Entering Table 2 at N = 25, we find for the lower limit a value of σ/s = .741 and for the upper limit a value of σ/s = 1.590. The .99 fiducial limits then are [1]

Upper: $\sigma = 1.590s = 1.590 \times 15$ pounds = 23.85 pounds;

Lower: $\sigma = .741s = .741 \times 15$ pounds = 11.12 pounds.

[1]Referring to the upper and lower .005 points of Table 1 when N = 25, these limits may be computed in the following manner.
Upper fiducial limit: $s/\sigma = 15/\sigma = .629$. $\sigma = 15/.629 = 23.85$ pounds.
Lower fiducial limit: $s/\sigma = 15/\sigma = 1.350$. $\sigma = 15/1.350 = 11.11$ pounds.

This does not mean that the probability is .99 that σ is between 11.11 and 23.85 pounds. But if .99 fiducial limits are stated for a very large number of random samples taken from one or several populations, the stated limits (which of course would vary from sample to sample) will enclose the population value about 99 times in 100. About once in 200 times σ will be larger than the upper fiducial limit, and about once in 200 times it will be smaller than the lower fiducial limit.

The accompanying tables were derived largely from Catherine M. Thompson, "Table of Percentage Points of the χ^2 Distribution," **Biometrika**, Vol. 32, Pt. 2, pp. 187ff. The relationship for Table 1 is $s^2/\sigma^2 = \chi^2/N$ where N = n + 1 and n means number of degrees of freedom. Values for the upper .001 point were similarly derived from R. A. Fisher and F. Yates, **Statistical Tables for Biological, Agricultural and Medical Research**, Table IV, p. 27. London: Oliver and Boyd, 1938. Values for the lower .001 point were computed from values of F at the upper .001 point with $n_1 = \infty$ shown in F. E. Croxton and D. J. Cowden, **Applied General Statistics**, p. 878. New York: Prentice-Hall, 1939. By inverting the F ratio we obtain $\hat{\sigma}^2/\sigma^2$ for the lower .001 points, where $\hat{\sigma}^2$ is the estimated population variance, and $n/N \cdot \hat{\sigma}^2/\sigma^2 = s^2/\sigma^2$. Table 2 (page 21) shows $\sqrt{N/\chi^2}$ values which were not obtained by taking the reciprocals of the $\sqrt{\chi^2/N}$ values of Table 1, but were computed from the same basic tables mentioned above. The upper and lower $\sqrt{\chi^2/N}$ values of Table 1 give the lower and upper $\sqrt{N/\chi^2}$ values of Table 2. For example, the lower and upper .998 fiducial limits for σ are respectively the reciprocals of the upper and lower .001 points for s.

That is, one divided by .430 (Table 2) equals 2.327 (Table 1). Similarly, one divided by .800 (P = .90 lower, N = 16, Table 2) equals 1.250 (P = .05 upper, N = 16, Table 1). And conversely, one divided by .800 (P = 10 lower, N = 27, Table 1) equals 1.250 (P = .80 upper, N = 27, Table 2).

TABLE 1—VALUES OF s/σ AT SELECTED PROBABILITY POINTS FOR VARIOUS SAMPLE SIZES

s is the standard deviation of the sample, σ is the standard deviation of the population, and N is the sample size. $\frac{s}{\sigma}=\sqrt{\frac{\chi^2}{N}}$, and $s=\sqrt{\frac{\chi^2}{N}}\,\sigma$. In χ^2 tables values are given for various degrees of freedom, where n=N−1.

N	Probability Points												N
	.001		.005		.01		.025		.05		.10		
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
2	.001	2.327	.004	1.985	.009	1.821	.022	1.585	.044	1.386*	.087	1.163*	2
3	.026	2.146	.058	1.879	.082	1.752	.130	1.568	.185	1.413	.265	1.239*	3
4	.078	2.017	.134	1.792	.169	1.684	.232	1.529	.297	1.398	.382	1.250	4
5	.135	1.922	.203	1.724	.244	1.630	.311	1.493	.377	1.378	.461	1.247	5
6	.187	1.849	.262	1.671	.304	1.586	.372	1.462	.437	1.358	.518	1.241	6
7	.233	1.791	.311	1.628	.353	1.550	.420	1.437	.483	1.341	.561	1.233	7
8	.274	1.744	.352	1.592	.394	1.520	.460	1.415	.520	1.326	.595	1.226	8
9	.309	1.704	.386	1.562	.428	1.494	.492	1.396	.551	1.313	.623	1.218	9
10	.339	1.670	.417	1.536	.457	1.472	.520	1.379	.577	1.301	.646	1.212	10
11	.367	1.640	.443	1.513	.482	1.453	.543	1.365	.599	1.290	.665	1.206	11
12	.391	1.614	.466	1.493	.504	1.435	.564	1.352	.617	1.280	.682	1.200	12
13	.413	1.591	.486	1.475	.524	1.420	.582	1.340	.634	1.272	.696	1.195	13
14	.432	1.570	.505	1.459	.542	1.406	.598	1.329	.649	1.264	.709	1.190	14
15	.450	1.552	.521	1.445	.557	1.394	.613	1.320	.662	1.257	.721	1.185	15
16	.467	1.535	.536	1.432	.572	1.382	.626	1.311	.674	1.250	.731	1.181	16
17	.482	1.520	.550	1.420	.585	1.372	.637	1.303	.684	1.244	.740	1.177	17
18	.495	1.505	.563	1.409	.597	1.362	.648	1.295	.694	1.238	.749	1.173	18
19	.508	1.492	.574	1.398	.608	1.353	.658	1.288	.703	1.233	.756	1.170	19
20	.520	1.480	.585	1.389	.618	1.345	.667	1.282	.711	1.228	.763	1.166	20
21	.531	1.469	.595	1.380	.627	1.337	.676	1.276	.719	1.223	.770	1.163	21
22	.541	1.458	.604	1.372	.636	1.330	.684	1.270	.726	1.219	.776	1.160	22
23	.551	1.449	.613	1.364	.644	1.324	.691	1.265	.732	1.214	.781	1.157	23
24	.560	1.439	.621	1.357	.652	1.317	.698	1.260	.739	1.211	.787	1.155	24
25	.569	1.431	.629	1.350	.659	1.311	.704	1.255	.744	1.207	.791	1.152	25
26	.577	1.423	.636	1.343	.666	1.306	.710	1.250	.750	1.203	.796	1.150	26
27	.584	1.415	.643	1.337	.672	1.300	.716	1.246	.755	1.200	.800	1.148	27
28	.592	1.408	.649	1.332	.678	1.295	.721	1.242	.759	1.197	.804	1.146	28
29	.599	1.401	.656	1.326	.684	1.290	.727	1.238	.764	1.194	.808	1.143	29
30	.605	1.394	.661	1.321	.689	1.286	.731	1.235	.768	1.191	.812	1.141	30

*Upon casual observation these upper values may appear to be too low. However they merely reflect the fact that s tends to be smaller than σ, especially when N is small. Computation will show that the **difference** between upper and lower values, at any probability level, is greatest for N=2 and decreases as N increases. Thus, for the .05 points, when N=2 we have 1.386−.0443=1.3417 and when N=3 we have 1.413−.185=1.228.

For values of N>30 compute $\sqrt{\frac{\chi^2}{N}}=\sqrt{\frac{n\left[1-\frac{2}{9n}\pm\frac{x}{\sigma}\sqrt{\frac{2}{9n}}\right]^3}{N}}$

where n=N−1 and x/σ is the normal deviate cutting off the corresponding tails of a normal distribution.

If limits for $\hat{\sigma}=\sqrt{\frac{\sum x^2}{N-1}}$, are desired they may be obtained from the values shown above by multiplying by $\sqrt{\frac{N}{N-1}}$

The above values are exact statements of the sampling limits of s around σ. If an estimate of σ based on a considerable amount of experience with a process that is under control, is used in place of σ, they are satisfactory approximations.

TABLE 2—VALUES OF σ/s FOR USE IN COMPUTATION OF SELECTED FIDUCIAL LIMITS OF σ FOR VARIOUS SAMPLE SIZES

s is the standard deviation of the sample, σ is the standard deviation of the population, and N is the sample size. $\frac{\sigma}{s}=\sqrt{\frac{N}{\chi^2}}$, and $\sigma=\sqrt{\frac{N}{\chi^2}}\,s$. In χ^2 tables values are given for various degrees of freedom, where $n=N-1$.

N	Fiducial Limits												N
	.998		.99		.98		.95		.90		.80		
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
2	.430	1,128.	.504	225.7	.549	112.8	.631	45.13	.722*	22.55	.860*	11.25	2
3	.466	38.72	.532	17.30	.571	12.22	.638	7.697	.708	5.408	.807*	3.773	3
4	.496	12.83	.558	7.468	.594	5.902	.654	4.305	.715	3.372	.800	2.616	4
5	.520	7.420	.580	4.915	.614	4.102	.670	3.213	.726	2.652	.802	2.168	5
6	.541	5.342	.599	3.817	.631	3.290	.684	2.687	.736	2.289	.806	1.930	6
7	.558	4.287	.614	3.219	.645	2.833	.696	2.379	.746	2.069	.811	1.782	7
8	.574	3.656	.628	2.844	.658	2.541	.707	2.176	.754	1.921	.816	1.680	8
9	.587	3.241	.640	2.587	.669	2.338	.716	2.032	.762	1.815	.821	1.606	9
10	.599	2.946	.651	2.401	.679	2.188	.725	1.924	.769	1.734	.825	1.549	10
11	.610	2.727	.661	2.259	.688	2.074	.733	1.841	.775	1.671	.829	1.504	11
12	.620	2.558	.670	2.147	.697	1.982	.740	1.773	.781	1.620	.833	1.467	12
13	.629	2.423	.678	2.057	.704	1.908	.746	1.718	.786	1.577	.837	1.436	13
14	.637	2.313	.685	1.982	.711	1.846	.752	1.672	.791	1.541	.841	1.410	14
15	.644	2.221	.692	1.919	.717	1.794	.758	1.632	.796	1.511	.844	1.388	15
16	.651	2.143	.698	1.865	.723	1.749	.763	1.598	.800	1.484	.847	1.368	16
17	.658	2.077	.704	1.818	.729	1.710	.768	1.569	.804	1.461	.850	1.351	17
18	.664	2.019	.710	1.777	.734	1.676	.772	1.543	.808	1.441	.852	1.336	18
19	.670	1.968	.715	1.741	.739	1.646	.776	1.519	.811	1.422	.855	1.322	19
20	.676	1.924	.720	1.709	.743	1.619	.780	1.498	.815	1.406	.857	1.310	20
21	.681	1.883	.725	1.681	.748	1.594	.784	1.480	.818	1.391	.860	1.299	21
22	.686	1.847	.729	1.655	.752	1.572	.787	1.463	.821	1.378	.862	1.289	22
23	.690	1.815	.733	1.631	.756	1.553	.791	1.447	.823	1.365	.864	1.280	23
24	.695	1.785	.737	1.610	.759	1.534	.794	1.433	.826	1.354	.866	1.271	24
25	.699	1.758	.741	1.590	.763	1.517	.797	1.420	.829	1.344	.868	1.264	25
26	.703	1.734	.744	1.572	.766	1.502	.800	1.408	.831	1.334	.870	1.256	26
27	.707	1.711	.748	1.555	.769	1.488	.803	1.397	.833	1.325	.871	1.250	27
28	.710	1.690	.751	1.540	.772	1.474	.805	1.386	.835	1.317	.873	1.243	28
29	.714	1.671	.754	1.526	.775	1.462	.808	1.378	.838	1.309	.875	1.237	29
30	.717	1.653	.757	1.512	.778	1.451	.810	1.367	.840	1.302	.876	1.232	30

*Upon casual observation these lower values may appear to be too high. However, they merely reflect the fact that s tends to be smaller than σ, especially when N is small. Computation will show that the **difference** between upper and lower values, for any pair of fiducial limits, is greatest for $N=2$ and decreases as N increases. Thus, for the .90 fiducial limits, where $N=2$ we have $22.55-.722=21.828$ and when $N=3$ we have $5.408-.708=4.700$.

For values of $N>30$ compute $\sqrt{\frac{N}{\chi^2}}=\sqrt{\frac{N}{n\left[1-\frac{2}{9n}\pm\frac{x}{\sigma}\sqrt{\frac{2}{9n}}\right]^3}}$

where $n=N-1$ and x/σ is the normal deviate cutting off the corresponding tails of a normal distribution.

If fiducial limits of σ are to be ascertained from $\hat{\sigma}=\sqrt{\frac{\sum x^2}{N-1}}$, the values shown above should be multiplied by $\sqrt{\frac{N-1}{N}}$

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The Difference Control Chart with an Example of its Use

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The efficiency of the control chart in detecting assignable causes of variation depends markedly upon its adaptation to the particular practical problem at hand. A decision as to the variables to be charted and the types of control charts to be kept should be determined only after a careful examination of all factors which contribute to the technique being employed. This leads to an important question.

Just what is a control chart? The author has heard many enlightening answers to this question, varying from the practical viewpoint to the purely theoretical definition. Of all the answers, however, one that deserves some reflection is: "The control chart is a technique for comparing observed external variation with an estimate of this quantity which is based on internal variance." That is to say, the average variation is determined within samples which are selected randomly from rational categories and the variation to be expected among sample means is estimated had all the samples been produced under a constant cause system, the observed variation among sample means being compared with this estimate. This principle can be applied either on the assumption that the measurements are free of error or steps can be taken to insure reproducibility of the measuring technique. In a large number of problems, reproducibility and accuracy of measurements is easily accomplished or at least errors in measurement are small compared to the magnitude of the variations being measured.

In the present discussion a case will be presented in which systematic variations in measurements may be several times the order of magnitude of the variations in quality being measured. Moreover, in the example presented strict reproducibility of measurements against a standard is costly, time-consuming and interferes with production schedules. In such instances, a special type of control chart known as the difference chart (to be defined later) may prove of considerable value in judging quality. Although the situation to be discussed is in the field of ballistics, it is believed that similar conditions exist in other fields and it is with this thought the problem is presented for general consideration.

In proving-ground tests of ammunition, velocity is determined by finding the time required for the projectile to traverse a measured distance between two "screens" placed at appropriate distances in front of the gun. A correction applied to the average velocity over the screen interval so obtained gives the velocity at the gun muzzle or "muzzle velocity." The range is defined as the horizontal distance a projectile travels. (In order to avoid confusion with the range, the term "maximum dispersion" will be used to designate the difference between the largest and smallest observations in a sample).

A firing table gives the range, i. e. the horizontal distance from gun muzzle the projectile should travel, for a given elevation of gun, standard meteorological conditions and prescribed muzzle velocity. In the ballistic acceptance test of projectiles, there are two important characteristics which must be measured in order to maintain uniformity in range. One is the level of muzzle velocity of projectiles and this depends markedly upon the tightness and diameter of the rotating band. For constant rotating band diameter, a loose band will cause a lower velocity than a tight one for a given powder charge. Since powder charge is determined by matching various lots of powder against a standard lot, it is important that for a fixed powder charge the velocity level of projectile lots from the same manufacturer (and also from different manufacturers) be maintained at a desirable level.

The other characteristic which must be measured is the "exterior ballistic" effect of the projectiles. That is, the distance the projectile will travel under given conditions of muzzle velocity, gun elevation and metro depends on the surface finish and dimensions of the projectile. In particular, a rough-surfaced projectile will give a shorter range than a smooth-surfaced one when both have the same dimensions and are fired at the same velocity. Thus, the importance of maintaining uniformity in both the tightness of rotating band and in the smoothness of surface finish of projectiles is apparent for accuracy in firing.

Figure 1 depicts a control chart on average muzzle velocity (10 round groups) and maximum dispersion in muzzle velocity for consecutive projectile lots of a single manufacture. The terms average "test" velocity and "test" velocity maximum dispersion are used since the manufacturer's product is under examination.

Figure 2 is similar to Figure 1 except that the observed range, rather than muzzle velocity, is the characteristic plotted. Control limits ($\pm \frac{3}{\sqrt{10}} \sigma$ for averages and .005 limits for maximum dispersion) are placed on the charts to indicate the relative amount of scatter.

All projectiles on which these charts are based were fired in a single gun with the same charge of standard powder, but generally speaking only one lot (10 round sample) was fired on a day. The

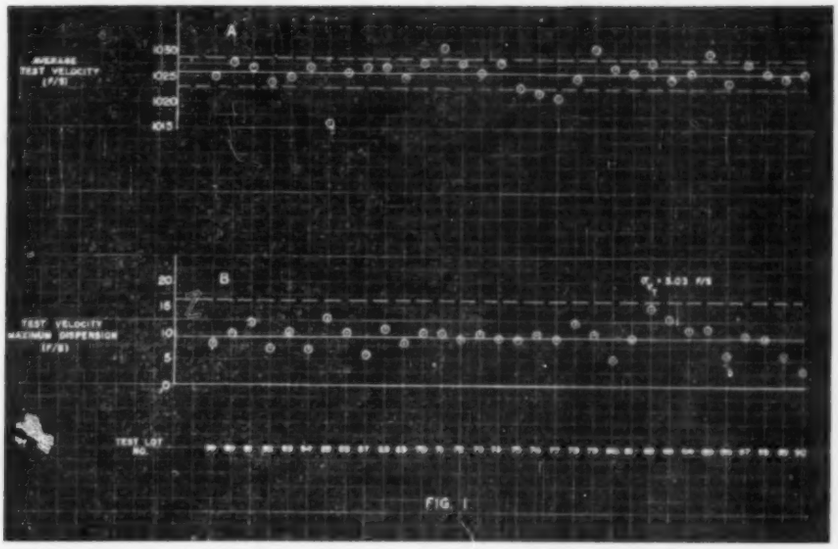

FIG. 1

problem is to determine whether or not the consecutive lots are alike in ballistic performance.

It is noted that the charts on test velocity maximum dispersion (Figure 1) and test range maximum dispersion (Figure 2) exhibit excellent control indicating comparable dispersion within lots. On the other hand, the charts on average test velocity (Figure 1) and average test range (Figure 2) exhibit a pronounced state of lack of control. Insofar as the chart on average test range is concerned, one would naturally expect this even for identical projectiles because meteorological conditions change from day to day, thus producing a definite effect on the "exterior ballistics" of the projectiles.

The chart on average test velocity exhibits lack of control either because of variations in quality of the presented product or because of what appears to be pure errors of measurement in velocity. As a matter of fact, in many instances proving ground tests show variations in calculated velocity level from day to day when firing from a single ammunition lot because of several reasons. The "screens" are not usually fixed because it becomes necessary to dismantle them from time to time in order to accommodate the variety of tests that have to be performed. Also, the gun may be used for several different types of test, various crews may be used for manning the gun, setting up the screens and measuring distances, taking velocity measurements, etc. Moreover, the "condition" of the gun bore varies due to the depositing of copper from rotating bands, heating of the tube and in some cases it may even be necessary over a period of time to change guns occasionally in ballistic acceptance tests of projectile lots. Suffice it to say that in the field of ballistics extreme care must be exercised to insure reproducibility of measurements. The main point, nevertheless, is whether or not it is economical to go to the trouble of accounting for and eliminating each and every variation in measuring technique.

The Ordnance Department handles this problem in a simple, practical and efficient manner. It has long been recognized by ballisticians that firing samples from a reference lot day after day in conjunction with test programs is worthwhile. The reference lot, which is chosen because of its homogeneity and desirable ballistic properties, serves as a standard of comparison and brings out variations, if present, in level of the measuring apparatus from day to day.

In the present problem, the reference projectiles (10 round samples) are fired alternately with test projectiles (using the same powder lot and powder charge) and velocity and range are measured on each round. Also, both test and reference rounds are conditioned to a temperature of 70°F prior to firing. Figure 3 depicts control charts on firings from the reference lot in conjunction with the various test lots (notice test lot numbers at the bottom of Figure 3). Occasionally, a test lot number appears and no reference firing is indicated. This is due to the fact that two test lots may be fired against a single reference sample on one particular day. The chart on average reference range is not shown since lack of control is to be expected here and Figure 2B depicts the comparable situation. From Figure 3 it can be seen that the charts on reference velocity maximum dispersion and reference range maximum dispersion indicate good control. One point is above the control limit for the chart on reference

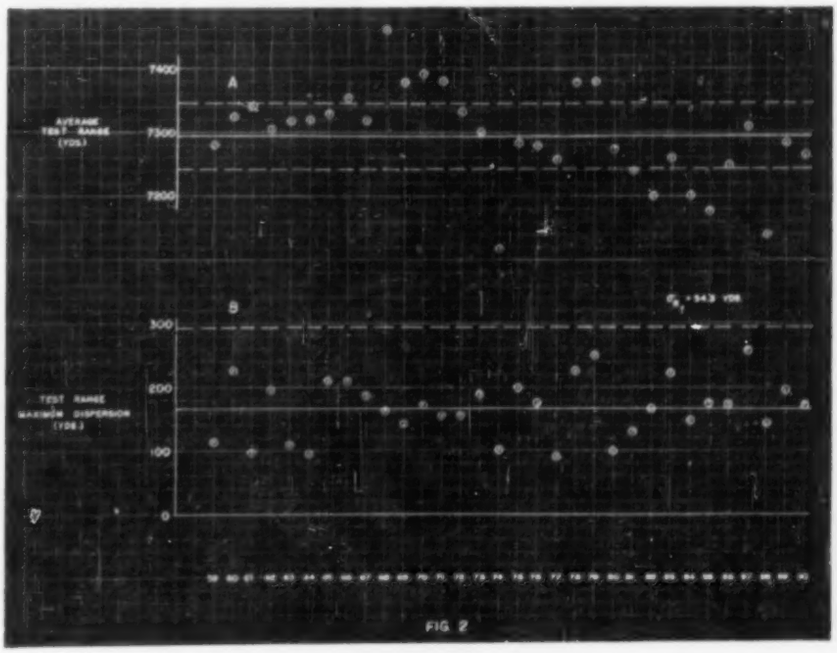

FIG. 2

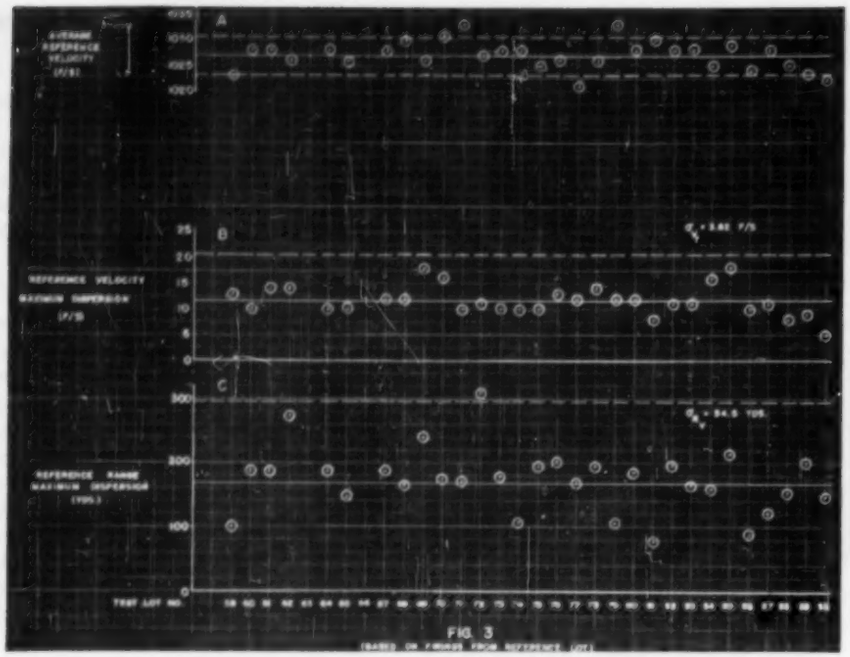

FIG. 3

range maximum dispersion — the reason for this has not been determined unless it is possibly a sampling error.

The chart Figure 3 on average reference velocity shows lack of control, indicating variations in the measuring technique[1] (on the assumption that the cause system of variability of reference lot is constant). It may have been possible to track down the cause for each point falling out of control at the time of the firing and precisely this was done in some instances during the initial stages of acceptance testing. Unfortunately, however, it usually takes hours to find the cause of each point outside control limits and in addition it is imperative that production schedules be maintained, especially during wartime. Moreover, a decision must be given immediately in most instances either to permit loading or not to permit loading of a particular projectile lot. Fortunately, it is not necessary to maintain strict control since a special type of control chart can be used to advantage in connection with test and reference firings.

In Figure 4, three "difference control charts" are given. Each point on chart A represents the difference in average velocities (10 round groups) of the test and reference rounds fired alternately on the same day. It is noted that for the consecutive test lots (each containing about 20,000 projectiles) we have unusually good control for differences in average muzzle velocity (indicating uniformity in tightness of rotating band for test lots). The limits for chart A are placed about the average difference in velocity at

$$\pm \frac{3}{\sqrt{10}} \sqrt{\sigma_{v_x}^2 + \sigma_{v_r}^2}$$

where $\sigma_{v_x}^2$ is the estimated internal variance in muzzle velocity for test lots and $\sigma_{v_r}^2$ is a like quantity for the reference rounds.

Chart B gives the difference in average ranges for test samples and reference firings. It is worth while to point out here that although there is lack of control in reference velocities and also variations in meteorological conditions, the acceptability of the test projectile lots for service can be judged. Control limits for chart B are placed at

$$\pm \frac{3}{\sqrt{10}} \sqrt{\sigma_{R_x}^2 + \sigma_{R_r}^2}$$

where $\sigma_{R_x}^2$ is the estimated internal variance in range for test lots and $\sigma_{R_r}^2$ is the like quantity for reference rounds.

Chart C, Figure 4, represents the surface effect (exterior ballistic effect) of test lots as compared to the reference lot. Each point on this chart is obtained in the following manner. The observed average range for each set of 10 test rounds is adjusted to a standard muzzle velocity of 1020 f/s. (1 f/s here represents about 9.9 yds. in range). The same is done for the 10 reference rounds fired with the test rounds. Thus, the difference between the adjusted average range of test rounds and the adjusted average range of reference rounds represents the difference in exterior ballistic properties — specifically, differences in surface finish — between test and reference rounds.

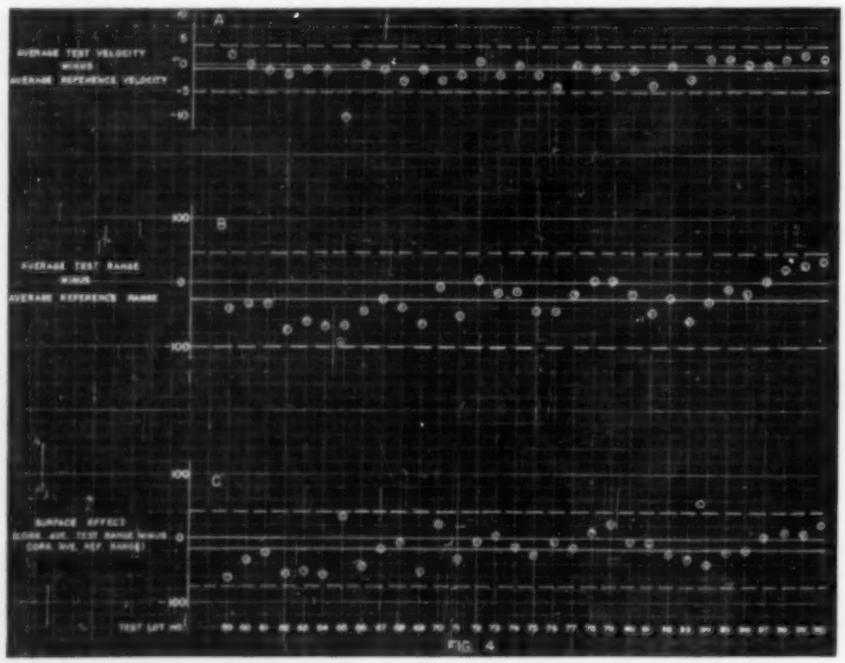

FIG. 4

[1] As a matter of fact, the variance in level of the measuring system from day to day is nearly four times as large as the random sampling variance of the average of a 10 round reference group (Figures 3A and 3B).

Control limits for the surface chart are placed at

$$\pm \frac{3}{\sqrt{10}} \sqrt{\left(\sigma_{R_x}^2 + \sigma_{R_r}^2\right) - b^2\left(\sigma_{v_x}^2 + \sigma_{v_r}^2\right)}$$

where the variances are defined above and b is the change in range for 1 f/s change in muzzle velocity. Actually, the significance of the quantity under the radical sign is that the variance in range is the sum of two components: (1) the variance in range caused by dispersion in muzzle velocity and (2) the variance in range attributed to variation in surface finish of the projectiles.

Test lot No. 65 which is out of control on difference in average velocity was reinspected for tightness of rotating band. All the other lots constitute a grand lot with respect to both the tightness of rotating band and surface finish. Hence, all of these projectile lots exhibit similarity in ballistic behavior and could be loaded into a single uniform ammunition lot.

The difference control chart has been used advantageously in an extreme type of case in which lots of the same manufacturer were not only tested in different guns but also at different proving grounds.

Of course, limits other than 3-sigma could be used on difference charts, depending on the particular circumstance. Another point of interest is that for the control charts shown there appears to be various cyclic trends; however, analysis of such trends is beyond the scope of this paper.

In conclusion, a simple but practical control chart technique has been presented for judging variations in quality for instances where it may not be economical to eliminate the cause of each and every change in level of the measuring apparatus.

The success of the difference control chart within the Ordnance Department is due largely to Colonel Leslie E. Simon, Director, Ballistic Research Laboratory, who recommended its application to the problem of manufacturing large and uniform lots of ammunition.

First Annual Forum, Michigan Section, Held in Detroit

REPORTED BY
CLARENCE KOOISTRA, HOOVER BALL AND BEARING COMPANY

The Michigan Section, American Society for Quality Control, ventured into a new field on Friday, June 7, when it sponsored an all-day Forum at the Book Cadillac Hotel in Detroit.

The attendance indicated a growing interest in matters of Quality Control in this area, and the program, broad in scope, supplied those attending with material worthy of consideration and retention. Leaders in their respective fields, gleaned from all over the eastern half of the United States, made this aim a definite possibility. That this was accomplished, was attested to by various persons interrogated by your reporter.

The program included morning forums of an introductory or a general nature, a noon luncheon and talk, afternoon forums on special topics and problems; and an evening dinner followed by another interesting talk.

Open time was spent at the various tool and gage exhibits and in the refreshment room where many a lively informal discussion was held and numerous problems were mutually solved.

The morning's Forum schedule included the following:

SUBJECT: Theory $\overline{X}$ and R Charts;
Chairman: Dr. Albert J. Swanson, General Motors Institute, Flint, Michigan.

The theory and use of average and range charts, as an aid in production control, were discussed. The advantages and benefits of their use was indicated, especially so where quantitative measurements can be taken. Time was allowed for the raising of problems and their solution.

SUBJECT: Theory of p Charts;
Chairman: Professor C. C. Craig, University of Michigan, Ann Arbor, Michigan.

An explanation of the use of "p" charts and their application to controlled quality and receiving inspection was given. It was shown how these charts were especially applicable where attributes rather than measures must be resorted to. Here, too, time was allowed for questions and discussions.

SUBJECT: Theory of Sequential Analysis;
Chairman: Professor William D. Baten, Michigan State College, East Lansing, Michigan.

Prof. Baten first indicated how a probability ratio led to two parallel lines on which sequential sampling plans rest. It was shown that these parallel lines were obtained when p_1, the acceptable quality limit for the lot; p_2, the unacceptable quality limit for the lot; α the maximum risk or probability of rejecting lots of quality p_1, or better; and β, the maximum risk or probability of accepting lots of quality p_2, or worse, were known. It was also shown that the slopes and dependent axis intercepts of these lines were determined solely from these four quantities. The nature of the sequential sampling plan was shown to depend, to a large extent, upon the difference between p_1 and p_2. Average numbers for acceptance and rejection were given for various values of p_2 when p_1, α and β were held constant. Several pairs of parallel lines were exhibited for different values of the above four quantities. Comparisons were made between double sampling plans and sequential sampling plans. Homograms were explained for securing the slopes and dependent axis intercepts of the parallel lines. Suggestions were offered for determining appropriate values for p_1, p_2, α and β for certain uses. A lively discussion pertaining to lot sizes followed.

The noonday luncheon afforded the chairman of the day, Mr. Walter Oliver, an opportunity of extending to the guests a word of welcome. A few remarks by the chairman of the noon luncheon, Major M. W. Blackwood, followed. He in turn introduced the feature speaker of the noon session, Mr. Frederick J. Halton, Deere and Company, Chicago, Illinois, who explained, "How to Introduce Quality Control to Top Management."

Mr. Halton got to his task in short order, showing first the necessity of getting top management interested in Quality Control. Even though Quality Control can function well, if started at the bottom of the executive ladder, it can function better if top management is vitally interested in its use. Only then can the program be properly coordinated and fitted into the over-all plant picture. With top management interested, it becomes possible not only to recognize and have knowledge of "variances" present but, even more important in a production line, it makes possible the vital factor for correction, namely, ACTION.

How top management at Deere and Company was introduced to Quality Control was then explained. This part of the address has been proviously briefed. Consult Page 10 of the May issue of INDUSTRIAL QUALITY CONTROL for this.

The afternoon program comprising fourteen sessions was divided into two groups, of seven each, which were run concurrently. This allowed guests to attend the two forums, most suitable to their requirements, during the afternoon. These forums included the following:

1) SUBJECT: Sequential Analysis;
Chairman: A. R. Jackson, Consultant, Palumbo and Jackson, Chicago, Illinois.

Most of the information covered in this forum has been proviously reviewed in INDUSTRIAL QUALITY CONTROL. This material, worthy of reference, can be found in the March issue, Pages 15 through 17 and the May issue, Page 25.

2) SUBJECT: Quality Control Methods for Short Runs and Job Shop Lots;
Chairman: Carl G. Schmid, Lucas-Harold Corporation, Indianapolis, Indiana.

Quality Control methods for short runs and job shop lots differ from those for production runs because the chances of effecting remarkable improvement in quality, which will result in tremendous savings, are much reduced, thus dictating economy in application. Furthermore, drastic modification of standard techniques may be indicated. The aim should be in the direction of improvement of the general level of quality rather than concentration on specific operations.

The basic requirement is the systematic gathering and dissemination of rejection data. This includes the whole field of statistical reporting. To be effective the results must be portrayed to management at all levels in the form of charts and reports which will compel action.

Coupled with the gathering of data should be the investigation of causes of rejections made by capable quality control engineers. The investigations should result in recommendations aimed at improvement of quality level and may include suggestions for changes in design, materials, finishes, methods of processing, assembly, etc.

A satisfactory quality control system can be based upon the two basic requirements given above. The new techniques based on the probability concept offer fine tools for further improvement of quality. The use of p charts develops naturally from the data gathered. As a further refinement on difficult jobs, $\bar{X}$ charts offer great possibilities when streamlined to make them economically justifiable on short runs. One method of accomplishing this is to establish control limits before starting a run, eliminate range charts, plot case values on chart, and visually estimate average instead of calculating it.

3) SUBJECT: Application of Fraction Defective Charts;
Chairman: Keith E. Ross, General Electric Company, Fort Wayne, Indiana.

(No report on this forum is permitted for publication.)

4) SUBJECT: Foundry Applications;
Chairman: A. E. R. Westman, Ontario Research Foundation, Toronto, Canada.

The May issue of INDUSTRIAL QUALITY CONTROL covers the material of this forum more completely than space here permits reporting. See pages 12-16.

5) SUBJECT: Inspection Plans for Continuous Production;
Chairman: H. F. Dodge, Bell Telephone Laboratories, New York, New York.

Material covered in this forum is not open for publication at this time.

6) SUBJECT: Training Personnel in Statistical Quality Control;
Chairman: R. E. Wareham, National Photocolor Corporation, New York, New York.

The importance of having trained personnel was indicated. Quality Control is an excellent tool for use in production, but, as with other tools, knowledge on how to use it is imperative.

Some possible steps in the training of personnel were then outlined and the floor was opened to discussion.

7) SUBJECT: Air Gaging in Quality Control;
Chairman: F. W. Blanchette, Moore Products Company, Philadelphia, Pennsylvania.

The "Air Gage" forms a valuable tool in the Quality Control field. Typical applications of this can be found in cases of fits and clearances. In most cases, the air gage replaces "go" and "not-go" gages, giving the advantages of a quantitative measure instead of an attribute judgment. It eliminates wear as a source of error and it reduces considerably the probability of matching extremes. This becomes possible since the air gage, as used on the machine, allows the operator to "explore" his work as to size and other conditions. Examples were cited giving witness both to the accuracy of the above statements and to the economic soundness of this method of gaging.

8) SUBJECT: Methods Applicable to High Production;
Chairman: Russell C. Trombly, Hoover Ball and Bearing Company, Ann Harbor, Michigan.

The following method has been used very successfully at the Hoover Company and it seems broad enough for general application.

Blank control charts for $\bar{X}$ and R were printed and mounted in glass covered cases on the machines. Regular samples of any predetermined number of pieces are drawn at random from the machine's production. Variable gages are used in checking the material and the results of these checks are plotted on the graphs. A "Standard Procedure" or routine is set up for the checker. This deals with his taking of the material and his actions on finding work "Out of Control." Data thus collected are analyzed by the Quality Control Department and action is taken by the individuals or departments responsible. Follow ups also form an important part of the routine.

9) SUBJECT: Receiving Inspection;
Chairman: Martin A. Brumbaugh, University of Buffalo, Buffalo, New York.

The threefold objective of receiving inspection is: quality protection, even flow of materials to fabrication and assembly, minimum cost of a "non-productive" department. The key to all three functions is sampling of large lots of incoming material. Many "simple" sampling plans were devised in receiving departments during the war, e.g., take a 5% sample, take a 10% sample, take a 25% sample, take a first sample of 300 and, if needed a second sample of 150, etc. Usually these plans provide for acceptance of the lot, if no defectives are found in the sample. Such plans are simple to operate, but they do not sort good quality lots from poor quality lots, the protection offered to both purchaser and vendor varies with lot size, and large lots will nearly always be rejected.

The operating principle in receiving inspection should be fixed protection to the purchaser against acceptance of poor quality material, and simultaneously fixed protection to the vendor against rejection of good quality material. This can be accomplished through the use of any one or a combination of three available acceptance plans: The Army Ordnance Plan, The Dodge-Romig Plan, or The Sequential Sampling Plan.

10) SUBJECT: Tool Wear;
Chairman: Paul Peach, North Carolina State College, Raleigh, North Carolina.

Reviewed in May issue of INDUSTRIAL QUALITY CONTROL, Page 23.

11) SUBJECT: Quality Control in the Chemical Industry;
Chairman: Charles A. Bicking, Hercules Powder Company, Wilmington, Delaware.

Reviewed in May issue of INDUSTRIAL QUALITY CONTROL, Page 24.

12) SUBJECT: Sub-Assembly Inspection;
Chairman: Halsey H. Kent, Eastman Kodak Company, Rochester, New York.

Ideal conditions for use of Sub-Assembly Inspection are obtained when Quality Control becomes responsible only to management. This eliminates problems of jurisdiction and action. Trained and diplomatic personnel is another prerequisite for successful operation.

By use of Sub-Assembly Inspection, focal points of trouble can be better eliminated. At this point engineering or the responsible department act to eliminate the cause.

Final results will then show that: final inspection can be reduced; assembly repair costs can be reduced; improved efforts by production will be noted; less departmental scrap will be made; inspection repairs can be reduced; and improved attitudes will be noted.

13) SUBJECT: Quality Control in Radio Industry;
Chairman: A. J. Winterhalter, Colonial Radio Corporation, Buffalo, New York.

Not available at time of going to press.

14) SUBJECT: Keeping Up to Date in the Gaging Field;
Chairman: R. E. Lilleberg, Sheffield Corporation, Dayton, Ohio.

Essentially, this forum was reported on Page 23 of the May issue of INDUSTRIAL QUALITY CONTROL.

The day's events came to a close with a Dinner Meeting in the ballroom. Dr. Brumbaugh, as chairman of the evening, brought home a pertinent fact when he said that Quality Control is like a disease in that it gets under your skin and spreads. He reported queries coming in from South Africa, Rio de Janeiro, and numerous other parts of the world. The presence of Dr. Kil Von Scheule of Sweden at the speakers table was more proof of this fact.

The program was then turned over to Dr. J. M. Juran of New York University, who had a vital mesage for the group. His subject, "Quality Control — A Management Tool," was very well put.

Dr. Juran pointed out that industry still has many sizeable problems ahead of it. These problems—such as getting out production schedules, improving the product, and reduction of the cost of manufacture—require all the tools at management's disposal. Like cost control, production control, and other sundry management tools, quality control has its place in the tool kit. It is up to the Quality Control Engineers to place it there.

To do this, it must be remembered that management is concerned primarily with results and not with the means used. Quality control groups and individuals are confronted with the problem of getting management to recognize the rightful place of quality control in the tool kit. Just as has been the case with some of the other tools, this may prove to be something of a problem, because application of quality control methods usually brings quick improvement and it is difficult to claim credit for the faulty operation thus corrected. However, where quality control can be demonstrated as a means to an end, it will be accepted by management.

Certain faults must be corrected before its rightful place can be attained. Thus far too much emphasis has been placed on techniques and their refinements rather than on the use of a pragmatic approach. Then, too, many have gone into industry with but very little industrial experience and floundered as a result. Also, there is a deficiency of really trained experts and consultants in the field. Finally, the quality control engineers must have a background of management and its problems before being ready to provide the answers. With these faults corrected and the programs expanded, the doors are wide open for its general recognition in the management tool chest in the not too distant future.

SOCIETY REPORTS

CHICAGO SOCIETY FOR QUALITY CONTROL

"Training Plant Personnel in Quality Control" was discussed at the Chicago Society's June meeting by Mr. Henry Becker who is currently engaged in teaching quality control methods to the personnel of the American Steel and Wire Company's Waukegan plant. Mr. Becker stressed the necessity of using a practical, shop approach to the problem of teaching industrial statistics and presented various mechanical devices which may be used to demonstrate the statistical nature of quality variations.

Through its program chairman, Mr. C. W. Richards, the Society has announced the completion of plans for a series of lectures on "Statistical Methods for Quality Control Engineers." These lectures, which will be held in addition to the Society's regular monthly meetings, are designed to serve as a refresher course for persons who have taken one of the War Production Board's training courses in quality control, or as an introductory course for those who have not had previous formal training in quality control statistics. Classes will be held on the evening of the third Wednesday of each month, beginning September 18. Teaching services will be donated by officers and members of the Chicago Society. This series is offered, without charge, to members and nonmembers alike who may attend as many of the lectures as they wish.

The ten lectures will deal with the following topics:

1. September 18: Fundamentals of Statistical Analysis, Measurement of dispersion and central tendencies.
2. October 16: Frequency curves, accuracy of measurement, methods of collecting data.
3. November 20: Explanation and construction of $\bar{X}$ and R charts.
4. December 18: Explanation and construction of p charts.
5. January 15: Explanation and construction of c charts, tool wear control charts, job shop control charts, and gridless charts.
6. February 19: Analysis of variance and chi-square technique and their application to industrial problems.
7. March 19: Correlation and its use in statistical quality control and the statistical determination of tolerances.
8. April 16: Probability theory and its application to methods of sampling.
9. May 21: Use of Sampling Tables.
10. June 21: Sequential analysis.

SOCIETY FOR QUALITY CONTROL STATE UNIVERSITY OF IOWA GROUP

The Barber-Colman Company of Rockford, Illinois, was host to the Society for Quality Control—State University of Iowa Group on May 24-25, 1946. Mr. B. F. Collins, Works Manager, and Mr. R. W. Hanna, Assistant Chief Inspector, demonstrated a few products of the company and discussed briefly the manufacture of some of them.

Interesting papers on the following subjects were presented: "Application of Statistical Quality Control to Plow Implement Manufacture," Mr. H. I. Martin, John Deere Plow Works, Moline, Illinois; "Explanation of Moving Range in Control Chart Technique," Professor Lloyd A. Knowler, State University of Iowa, Iowa City, Iowa; "Some Applications of Quality Control to the Hybrid Corn Industry," Mr. Delmar E. Henderson, Production Research Assistant and Mr. Simon Casady, Statistician, Pioneer Hi Bred Corn Company, Des Moines, Iowa; and "Use of Correlation in Quality Control," Miss Nancy Bruner, Statistician, Western Auto Supply Company, Kansas City, Missouri. Mr. Wayne M. Biklen, Quality Control Engineer, Sheaffer Pen Company, Fort Madison, Iowa, was Program Chairman. Mr. E. L. Fay, Chief Inspector, John Deere Tractor Company, Waterloo, Iowa, and president of the society, introduced the speakers and presided at the discussion periods.

Mr. James M. Ballowe, Manager of Inspection, Alden's, Inc., Chicago, Illinois, reported on the success of the Mid-West Quality Control Conference sponsored by the Chicago, Illinois, Northwestern, Indiana, and Iowa Societies. Professor Knowler reported on the formation of the American Society for Quality Control.

The meeting was concluded by an interesting and very instructive trip through the Barber-Colman plant under the guidance of Mr. Hanna, and Mr. Ernest E. Hintz, Director of Training.

BOSTON SOCIETY FOR QUALITY CONTROL

The annual meeting of the Society was held June 6 at the Boston City Club. At the business session all of the present officers were re-elected for the coming year. Plans are afoot for a New England Quality Control Conference next November. A planning committee has been set up with Mr. G. J. Meyers, Jr., of Manning, Maxwell and Moore as Chairman.

Following the business session, Mr. F. J. Healy, Vice-President, Sylvania Electric Products, spoke on "What Management Gains from Quality Control." He stated plainly that management decisions in his company are made on the basis of quality control reports and that management is delaying long range decisions in other areas until newly installed quality control operators have had an opportunity to function.

Mr. George D. Edwards, President, American Society for Quality Control, presented the current status and future plans of the American Society. His talk, which was very well received, showed the great amount of steady and careful consideration being given to this activity.

THE DELAWARE QUALITY CONTROL SOCIETY

The Delaware Quality Control Society, at its last meeting of the season on May 6, elected the following officers for 1946-47: Chairman, Howard S. Clark; Vice-Chairman, William H. Markwood, Jr.; Secretary-Treasurer, Dr. John R. Vincent; Program Committee, Charles A. Bicking; Membership Committee, Arthur R. Kalmbacher.

At this same meeting Major Frank Grubbs, of the Ballistic Research Laboratory, Aberdeen Proving Grounds, discussed the development and use of "Difference Control Charts." [Editor's Note: The complete text of this paper appears on pages 22 to 25 of this issue.)

THE ATLANTA QUALITY CONTROL SOCIETY

The Society met in Atlanta, Georgia, on May 24, 1946. During the business session, the following officers were elected: President, Cleveland L. Adams, Head, Processing Department, Research Division, West Point Manufacturing Company, Shawmut, Alabama; Vice-President, John H. Reynolds, Celanese Corporation of America, Rome, Georgia; Secretary-Treasurer, Mary Jo Wesson, Research Division, West Point Manufacturing Company, Shawmut, Alabama; Authorized Representative to the American Society for Quality Control, Dr. Ralph Hefner, Dean of Special Studies, Georgia Tech, Atlanta, Georgia; alternate, E. H. Turner, Wynne Precision Company, Griffin, Georgia.

All members affiliated themselves with the National Organization. Dr. Ralph Hefner, representative from the Atlanta group, gave a report on the founding of the American Society for Quality Control. At the dinner session, Mr. Frank F. Groseclose, Head of the Industrial Engineering Department, Georgia School of Technology, gave a paper on "Why Management is Interested in Quality Control."

PHILADELPHIA SECTION, AMERICAN SOCIETY FOR QUALITY CONTROL

At the regular May meeting, the Philadelphia Quality Control Society adopted a new constitution and by-laws that would be in agreement with the new National Organization. Hereafter, we will be known as the Philadelphia Chapter, American Society for Quality Control.

Election of officers for the new fiscal year brought the following: Chairman, I. S. Hoffer; Vice-Chairman, F. R. Bailey; Secretary, E. M. Schrock; Treasurer, J. A. Jones; Representative to American Society for Quality Control, H. W. Poole; Editor, E. M. Schrock.

Mr. J. A. Jones of Westinghouse Electric Corporation read a paper on "Application of the Control Chart Method to the Control of Quality." This pointed out the advantages of Quality Control over other control methods in the manufacture of small and large lots of varying sizes of turbine blades, and that, as is often the case, several operations could be controlled by controlling one particular operation.

Under the guidance of Professor I. S. Hoffer and his various committees, we have just ended a successful year and look forward to a better one for 1946-47. We expect the growing Quality Control interest in this district to result in greater future activity and a larger membership.

OHIO QUALITY CONTROL SOCIETY

The Ohio Quality Control Society does not intend to have meetings during the summer months. Our Executive Committee is meeting regularly throughout the summer, however, in an attempt to provide the best in the way of meetings during the following year. Mr. Wade R. Weaver, as Chairman of the Program Committee, is in the process of developing an interesting series of lectures for the ensuing meetings.

Considerable emphasis is being placed on increasing the membership in the Ohio Quality Control Society and Mr. C. H. Beresford has been appointed as Chairman of the Membership Committee. Mr. Wendell H. Abbott and Mr. D. K. Wright, Jr., will head up the Technical and Educational Committees, respectively.

SOCIETY OF QUALITY CONTROL ENGINEERS OF SYRACUSE

Two meetings of the Society, May 7 and June 4, were held at the Hotel Syracuse and Bristol Laboratories respectively, and were devoted to discussions of problems of control related to the manufacture of penicillin and other pharmaceuticals. Papers presented at both meetings were by members of the Bristol Laboratories staff.

The May 7 program was as follows: "Penicillin Manufacture," Harry V. Zahm; "The Penicillin Assay," George A. Hunt; "Quality Control as Applied to the Penicillin Assay," Roland H. Noel. Discussion following these papers was chiefly concerned with methods of measurement of inhibition zones in the penicilln assay and the use of control charts to demonstrate improvements in methods of assays.

The June 4 program consisted of dinner in the Bristol Laboratories cafeteria, followed by an inspection of the penicillin plant. The program which followed the tour was as follows: "The Construction and Operation of the Multiple-head Penicillin Filling Machine," Charles Monroe; "Analytical Methods Used for Determining Uniformity of Penicillin Filling," Richard Downing; "Analysis of Filling Data and Application of Control Charts to the Filling Operation," Roland H. Noel.

There has been little work done in the application of Statistical Qualty Control methods to the manufacture of pharmaceuticals, and the meetings and subsequent discussions demonstrated that quality control principles may be applied to manufacture of pharmaceuticals and should prove to be just as valuable in penicillin manufacture as in other industries.

As in other industries, Quality Control by statistical methods can be applied to raw material acceptance, process control, laboratory control and analysis of factory data. Pharmaceutical management will also come to use quality control for, as in other businesses, it can be applied to records, reports and other management control devices. Of major importance is the application of statistical design and method of analysis in research and development. There is no doubt that such a tool will be just as important to the research worker as is the complicated equipment with which he carries on his never-ending search for more effective drugs and chemicals.

QUALITY CONTROL ENGINEERS OF ROCHESTER

The final meeting until the fall season was held at the Rochester Chamber of Commerce on Tuesday, May 21, 1946.

The first part of the meeting was devoted to the election of new Officers and Directors for the year 1946-47. Mr. D. C. Larmouth, Chairman of the Nominating Committee, presented the following nominees for office: Officers: President, H. H. Kent, Eastman Kodak Company, Camera Works; Vice-President, J. A. Tilton, General Motors, Delco Appliance Division; Secretary and Treasurer, R. E. Golemb, Stromberg-Carlson Company. Directors: R. K. Dean, E. I. duPont, Defender Division; R. H. Eisenhart, Bausch & Lomb Optical Company; E. W. Moore, Ritter Company, Inc.; E. P. Mynott, General Motors, Rochester Products; J. C. Nilsen, Taylor Instrument; Dr. G. T. Wernimont, Eastman Kodak Company, Kodak Park.

Motion was made and approved that the nominees be accepted and installed.

Mr. Alfred L. Davis, Treasurer of the American Society for Quality Control, the retiring President, was presented with an Honorary Life Membership to the Quality Control Engineers of Rochester in recognition of the excellent job he had done in organizing the Quality Control Engineers of Rochester and the capable service rendered as a two term President of the organization.

The second half of the meeting was high lighted with a very interesting presentation by Dr. Grant T. Wernimont of Eastman Kodak Company, on "The Use of Control Charts in the Chemical Laboratory." The usual question period followed the meeting in which 185 members participated.

A considerable amount of interest is shown in the sub-group meetings covering "Sampling" and "Gage Control." On April 23, 1946, approximately 40 members attended a meeting covering "Sampling in the Receiving and Automatic Screw Machine Areas," which was very ably presented by Mr. Stanley Collins and Mr. Ray Foos. The Gage Control group met April 1, 1946 to hear a very interesting presentation by Mr. Emmett W. Moore of Ritter Dental Company, Inc. on "Wear Allowances on Screw Thread Gages." The new officers of the Gage Control group for the ensuing year are: Chairman, William L. Myers, Gleason Works; Co-Chairman, P. Fishback, Graflex, Inc.

SAINT LOUIS SECTION AMERICAN SOCIETY FOR QUALITY CONTROL

The St. Louis Secretary writes us that he will vote for a 48 hour day so that his chapter can catch up on their homework—constitution writing, committee appointments and development, executive meetings, minutes and now as an active member representing his chapter of the Second Midwest Quality Control Conference Program. Mr. Madaus of the White-Rodgers Electric Co. made a flying trip to Chicago to extend his chapter's assistance where it can be of most value.

It is also reported that this chapter is growing — now having 34 members — rate of growth is naturally slow, but results already indicate a more rapid growth in the fall.

At the May 17 meeting the chapter felt very fortunate in having Mr. C. W. Kennedy of the Federal Products Corp. His talk covered brief pictures of various applications and results of Quality Control and was labeled "Some Random Samples of Quality Control." For the most part very little reference or discussion was given to statistics. Let's say it was a very practical, easily understood, and most interesting informal type of talk. The meaty and varied applications of Quality Control were just the thing that was needed to awaken the audience to the realization of the untold limits and value of a Quality Control Program. This chapter highly recommends this speaker because of his vast experience and because the subject matter is the type needed by all of us — but more so by the new and younger societies.

SOCIETY FOR QUALITY CONTROL, NORTHEASTERN INDIANA

The Society's meetings are held the second Wednesday of each month at 8 p.m. at the Purdue University Center in Fort Wayne. All out of town Society members are cordially invited to attend our meetings when in this area.

At the February 13 meeting, Mr. L. E. Quinnell, Magnavox Company, spoke on "Management Points of View Relative to Quality Control." Mr. J. M. McDowell discussed "The Application of Statistical Methods to Analyze the Quality of Resistors vs. Vendors."

At the March 13 meeting, Mr. R. D. Long, International Harvester Company, opened the discussion on "Quality Control as Pertains to Automotive Gears," and introduced Mr. Ray Snyder who presented a very vivid demonstration of proper gear design and cutting.

SOCIETY OF QUALITY CONTROL ENGINEERS OF CALIFORNIA

The Society held a dinner meeting at Hotel Mayfair in Los Angeles, June 13.

A special program was arranged with Professor Eugene L. Grant of Stanford University as guest speaker. He spoke under the title, "Statistical Quality Control in the Manufacture of Consumers' Goods." He told of the recent quality control developments in the textile and food industries. He also traced the growth of statistical quality control in the country as a result of the numerous statistical quality control courses offered during the war.

NEWARK SOCIETY FOR STATISTICAL QUALITY CONTROL

On May 23, the Society held a joint meeting with the Society for the Advancement of Management, Northern New Jersey Chapter. The Chairman of this meeting was Professor J. M. Juran of New York University. Frederick J. Halton, Jr., Deere and Company, spoke on "Presenting Quality Control to Management." The discussion period, which followed, was led by D. F. Copell, Wagner Baking Corporation, and Ralph E. Wareham, National Photocolor Corporation.

SOCIETY OF QUALITY CONTROL ENGINEERS OF BUFFALO

The Buffalo Society met in St. Vincent's Hall, Niagara University, on Monday, June 24th. Rolly W. Fitch, Chief Engineer of the Auto-Lite Battery Company, was the chairman on this occasion.

The first speaker was Myron Cory of the National Carbon, who talked on Control in Non Mass Production Operations. He told how in processing graphite electrodes, statistical applications had in one year improved control, saved considerable time in locating sources of trouble, and enabled his company to foresee and prevent scrap on one item amounting to $15,000.

The second speaker, Vernon Grom, secretary of the Buffalo Society, talked on Special Applications of Control Chart Principles. He outlined the Demerits Per Unit method of reporting quality as developed by the Westinghouse Electric Company.

H. J. O'Connor of the Electro Metallurgical Company, Niagara Falls, New York, concluded the program with a talk on the relationship of the i and the e to the Average and Standard Deviation of the Binomial Distribution. Mr. O'Connor pointed out that the use of the i and e to shorten certain mathematical computations would undoubtedly be a requisite part of the equipment of future quality control operators.

The Society voted to have forums in the future for those who have control problems of a specialized nature and who would benefit by a discussion of mathematical developments.

American Society News

EXECUTIVE COMMITTEE MEETS

The Executive Committee of the American Society held a seven hour meeting at the Harvard Club in New York on 22 May, 1946. Present were Messrs. George D. Edwards, Andrew I. Peterson, Ralph E. Wareham, Charles J. Hudson, Wade R. Weaver and Frederick J. Halton, Jr. Reports from the Executive Secretary, from the Treasurer and from the Chairman of the Editorial Board were considered and accepted. A large number of matters came up for discussion, and several of the decisions reached will be of immediate interest to the general membership of the Society:

Advertising In Industrial Quality Control

The Executive Committee unanimously approved appointment by the President of a Committee on Professional Ethics and Qualifications. The matter of personal consultant advertising in INDUSTRIAL QUALITY CONTROL was referred to this new Committee for study and recommendations. The Executive Committee decided that no personal consultant advertising will be accepted until it has received and considered these recommendations. In the meantime, the Editorial Board and the Committee on Publicity and Public Relations are urged to be aggressive in their search for advertising of types which are currently acceptable.

Recognition of New Local Societies

The Executive Committee agreed that the welfare of the American Society as a whole will best be served by encouraging the strengthening of all local groups, old and new. Exclusive assignment of relatively large geographical areas to local Societies was felt by the Executive Committee to be of questionable advisability. It was agreed that the legitimate desires of local members must be recognized irrespective of present territorial assignments, so that if a local group of some proportions wishes to form itself into a society, an existing Society whose primary activities are in a more or less separate locality should not ordinarily prevent such action.

A tentative decision was reached that the area to be exclusively assigned hereafter to a local Society, would ordinarily be limited to that within about fifty miles of the headquarters of that Society. At the same time however, it was agreed that local circumstances would probably dictate rather flexible administrative interpretation of the fifty-mile rule,—so that substantially larger sparsely settled areas might be assigned to individual Societies where desirable, while large metropolitan areas might in some cases even be divided among two or more Societies.

Local Society Fiscal Years

The Executive Committee unanimously decided to urge all local Societies to make their fiscal years coincide with that of the American Society,—that is, to begin on 1 July and terminate on 30 June.

Local Society Names

The point was brought out that three of the local Societies had names which did not identify them in any way with the localities in in which they operate. This has led, in a number of instances, to the mistaken conclusion that these Societies are in competition with the American Society. One of these Societies (Michigan) has recently changed its name so that it has overcome this objection. The Executive Committee felt that the remaining two Societies should individually seek early solution to the problem by incorporating into their names suitable reference to the locality with which they are identified.

Reference to the local Societies as "chapters" or "groups" of the American Society was not looked upon with favor by the Executive Committee. Their designation as "Sections" of the American Society was generally endorsed,—it being pointed out that this procedure is followed by the American Institute of Electrical Engineers and by several other national organizations. It was agreed that the executive head of a "Section" would best be designated as its "Chairman" rather than its "President."

American Society Emblem

The Executive Committee adopted as the emblem of the American Society, the greek letter sigma with the name of the American Society around its periphery and with a replica of a quality control chart in its central portion.

American Society Convention

The Executive Committee looked with favor on the suggestion that a general meeting or convention of the American Society be held some time after the beginning of 1947. It was first proposed that this general meeting be combined with the Annual Meeting of the Society. It was pointed out, however, that the Annual Meeting must be held on the fourth Friday in June, and that this date could be changed only by amendment of the by-laws which would be undesirable. It was agreed that the preferred time for any general meeting would be during the winter or early spring season—well before the approach of warm weather. The Executive Committee referred to the President the matter of developing further arrangements for a first Convention of the American Society to be held in a suitable mid-western city sometime during the preferred period mentioned.

Additional Local Societies Affiliated

During the past two months, three additional Local Societies have become Sections of the American Society for Quality Control, viz:

Western Massachusetts Society for Quality Control.

Society for Quality Control—Northeastern Indiana.

Hartford Society for Management and Control.

In the meantime, the Northwestern Society has been merged into the Chicago Society, so that the American Society is now composed of twenty-two Local Sections.

The three new sections mentioned above, together with the St. Louis Section, have still to designate their members on the Board of Directors of the American Society.

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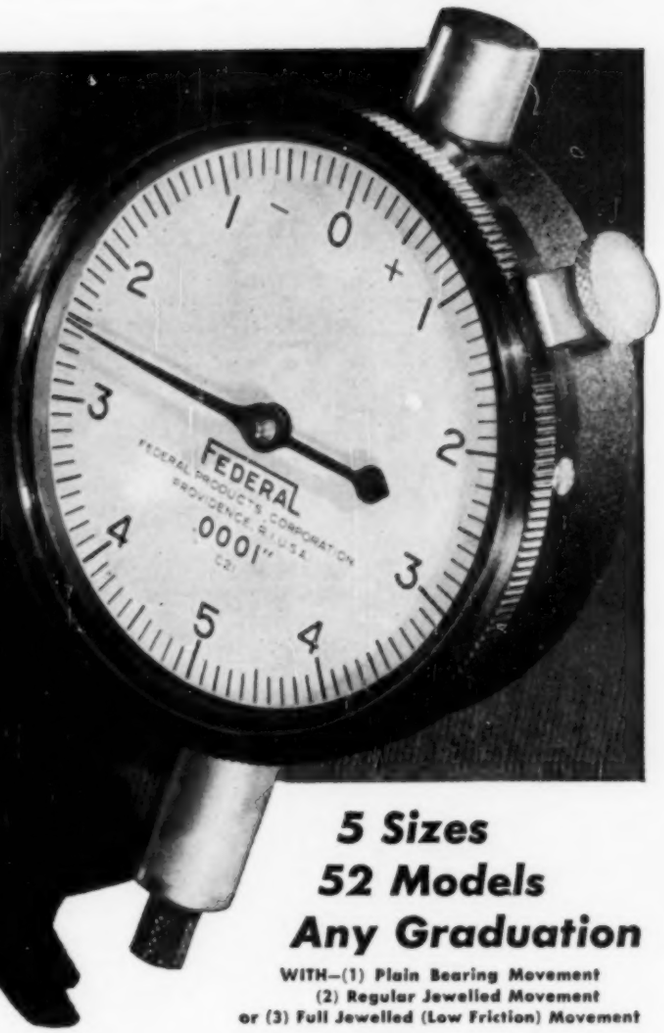

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